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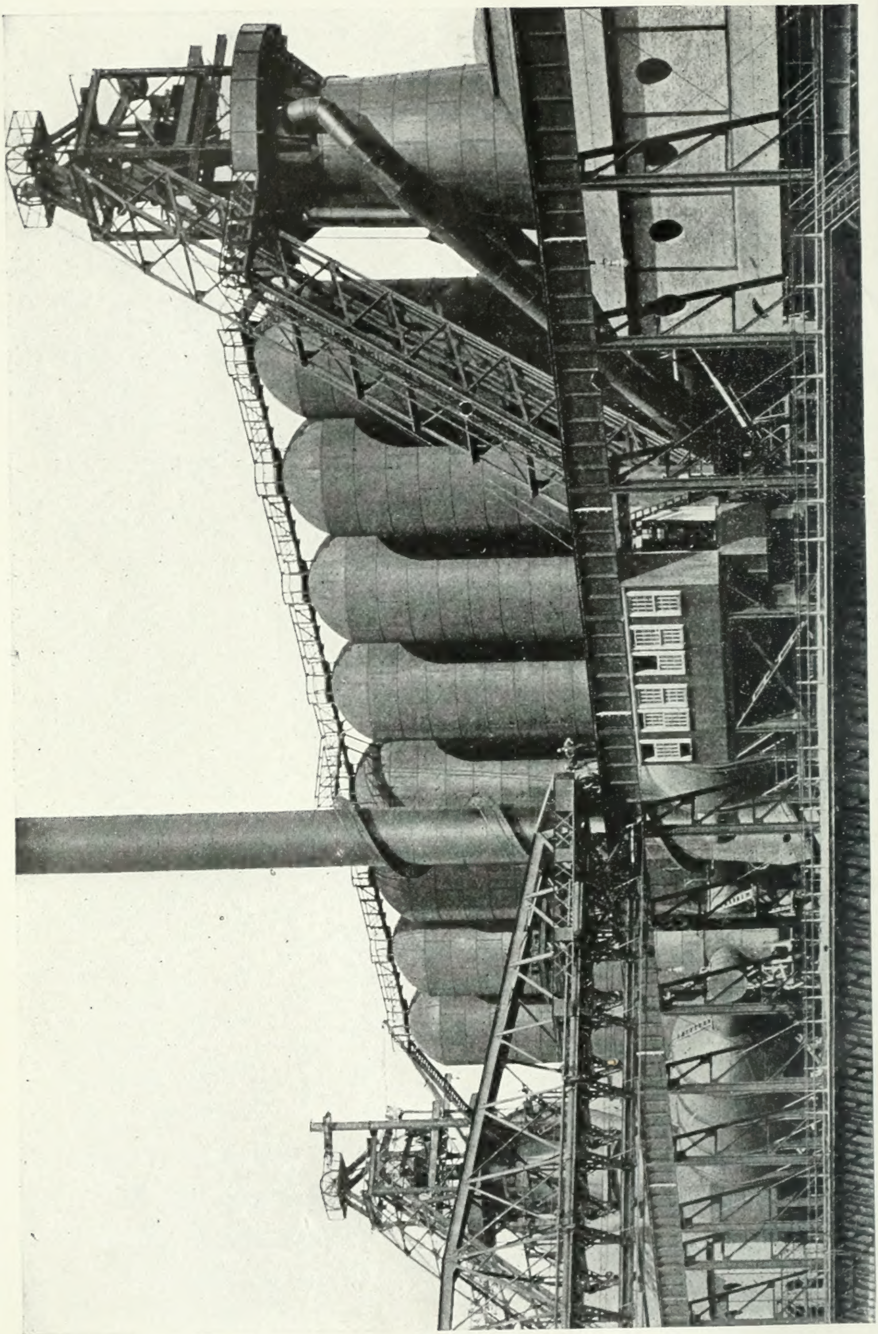

Cyclopedia
of
Mechanical Engineering

A General Reference Work

ON MACHINE SHOP PRACTICE, TOOL MAKING, FORGING, PATTERN MAKING, FOUNDRY WORK, METALLURGY, STEAM BOILERS AND ENGINES, GAS PRODUCERS, GAS ENGINES, AUTOMOBILES, ELEVATORS, REFRIGERATION, SHEET METAL WORK, MECHANICAL DRAWING, MACHINE DESIGN, ETC.

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Grateful acknowledgment is here made also for the invaluable co-operation of the foremost manufacturers and engineering firms, in making these volumes thoroughly representative of the best and latest practice in the design and construction of steam and gas engines, machine tools, and other classes of modern machinery; also for the valuable drawings and data, suggestions, criticisms, and other courtesies.

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Foreword

THE rapid advances made in recent years in the field of Mechanical Engineering, as seen in the evolution of improved types of machinery, new mechanical processes and methods, and even new materials of workmanship, have created a distinct necessity for an authoritative work of general reference embodying the accumulated results of modern experience and the latest approved practice. The Cyclopedia of Mechanical Engineering is designed to fill this acknowledged need.

¶ The aim of the publishers has been to create a work which, while adequate to meet all demands of the technically trained expert, will appeal equally to the self-taught practical man, who, as a result of the unavoidable conditions of his environment, may be denied the advantages of training at a resident technical school. The Cyclopedia not only covers the fundamentals that underlie all mechanical engineering, but places the reader in direct contact with the experience of teachers fresh from practical work, thus putting him abreast of the latest progress and furnishing him that adjustment to advanced modern needs and conditions which is a necessity even to the technical graduate.

¶ The Cyclopedia of Mechanical Engineering is based upon the method which the American School of Correspondence has developed and successfully used for many years in teaching the principles and practice of engineering in its different branches. It is a compilation of representative Instruction Books of the

School, and forms a simple, practical, concise, and convenient reference work for the shop, the library, the school, and the home.

¶ The success which the American School of Correspondence has attained as a factor in the machinery of modern technical and scientific education, is in itself the best possible guarantee for the present work. Therefore, while these volumes are a marked innovation in technical literature—representing, as they do, the best ideas and methods of a large number of *different* authors, each an acknowledged authority in his work—they are by no means an experiment, but are in fact based on what has proved itself to be the most successful method yet devised for the education of the busy workingman. They have been prepared only after the most careful study of modern needs as developed under the conditions of actual practice in the Machine Shop, the Engine Room, the Drafting Room, the Factory, etc. The formulæ of the higher mathematics have been avoided as far as possible, and every care exercised to elucidate the text by abundant and appropriate illustrations.

¶ Numerous examples for practice are inserted at intervals; these, with the test questions, help the reader to fix in mind the essential points, thus combining the advantages of a textbook with those of a reference work.

¶ Grateful acknowledgment is due the corps of editors and authors—engineers and designers of wide practical experience, and teachers of well-recognized ability—without whose co-operation this work would have been impossible.

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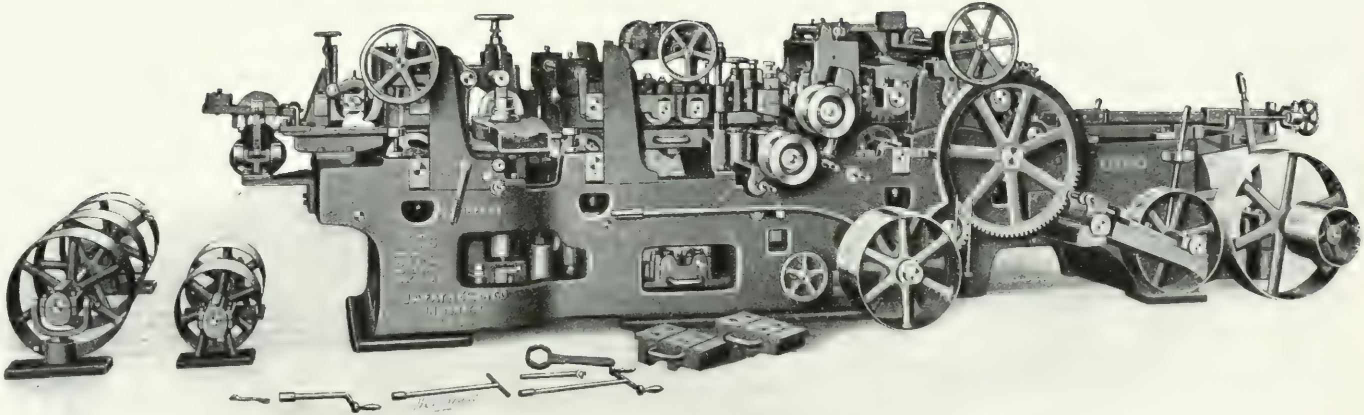

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PATTERN MAKING.

PART I.

PATTERN MAKING dates back to the time when the first article was made from molten metal for the use of man. The pattern must precede the making of its metal counterpart, and is therefore the first subject to be treated in the working of metal.

Qualifications of the Pattern Maker. The pattern maker is essentially a worker in wood, though, where many castings are to be made from the same pattern, the final or working pattern is made of metal. These metal patterns are very serviceable, and leave the sand more easily and cleanly than those made of wood. Metal patterns are always necessary when the work is of a delicate or very light character. In all such cases, however, the first pattern —from which the metal pattern is to be moulded—is made of wood, allowance being made for double shrinkage, and, when necessary, for double finish. The necessity for this will be clearly explained farther on.

The pattern maker should possess a practical knowledge of the properties of metals. First of all, he must understand the **shrinkage** of metals, that is to say, how much smaller the cold casting will be than the molten mass as it flows into the mould; he should know what the **strength** of the metal is; he should be familiar with the relative **rapidity of cooling,** so that internal stresses in the body of the completed casting may be avoided as much as possible; he also should know enough about the practical work of the moulder to decide upon the peculiarities of construction of the pattern for any given piece; and he must be sufficiently skilled as a draftsman to lay out, without the assistance of the designer, the drawings of the piece to be made. It is very true, however, that there are many good pattern makers who do not possess all of these qualifications.

The last-mentioned qualification is one of the most important. The drawings furnished the pattern maker are usually on a small scale.

In order to work to the best advantage, he must reproduce a part or all of them at full size, as working drawings. To do this to such a way that the lines and curves of the finished pattern shall be graceful and artistic in appearance, will require the same nicety and precision of workmanship that are demanded in the drafting room, and it is essential that the pattern maker have the same complete knowledge of the principles involved. To the extent. then, of being able, when necessary, to make a full-sized drawing of the article to be made, the pattern maker must be a draftsman.

In large establishments, where all the work comes to the pattern shop in the form of carefully executed drawings, the pattern maker is the means of putting the ideas of others into tangible shape. In smaller places, where no draftsman is employed, the pattern maker will be called upon to work out the designs for which he is to make his patterns, and he thus becomes the real designer.

Finally, the pattern maker is seldom required to make two patterns that are identically the same. His work, therefore, is varied, and he must be prepared to apply to the solution of new problems that arise such principles as he may already have learned.

Materials for Patterns. As patterns are subjected to more or less rough usage, and are alternately wet and dry, it follows that the ideal material is one whose hardness is such that it will withstand the wear and tear of handling and at the same time be impervious to the effects of moisture. Such material is to be found in the metals, but, as the cost of working these into the proper shape is considerable, some kind of **wood** is usually substituted.

Kind of Wood Used. If, then, wood is to be used, another qualification is to be added—namely, it should be easily worked. The best wood for the purpose is undoubtedly **white pine.** Care should be exercised in the inspection of the wood, to see that it is **clear, straight-grained,** and **free from knots.**

The straightness of the grain can be determined by the appearance of the sawn face. This should present an even roughness over the whole surface. The wood should be *seasoned* in the open air, but preferably sheltered by a roof, and should be piled so that the air will have free access to all parts of the plank. In the natural process of air drying, the moisture slowly works out to the surface and evaporates until the wood is dry or "seasoned." Such stock is firmer, stronger, more elastic, and less affected by heat and cold and by moisture and dryness, than kiln-dried lumber. In kiln drying, the outside surfaces and ends of the boards are dried more rapidly than the inside, producing strains that cause the wood to bend and warp while the pattern is in the process of construction. For this reason it is better to "build up" the larger pieces of a pattern by gluing together three or more (*never two*) pieces of thinner stock. When the patterns are of moderate size the stock to be glued may vary from ⅜ inch to 1 inch or even 1¼ inches in thickness, in proportion to the size required. Stock of 2 inches thickness or over can seldom be found sufficiently seasoned; and, if forced by kiln-drying, it will be checked and strained to an extent that will render it useless for pattern work.

While pine is in general the ideal wood for pattern work, it is soft and weak, so that, if small and strong patterns are desired, a harder wood is usually employed. **Mahogany** is much used for this purpose. Like pine, it is not liable to warp, and, when straight-grained, it is worked with comparative ease There are many varieties of this beautiful wood, varying greatly in firmness of texture. The soft bay wood, often sold as genuine mahogany, should be avoided for patterns, being but little harder than pine. **Cherry** is also extensively used, but is not so easily worked to a smooth surface as mahogany, and is more liable than the latter to warp and to be affected by moisture. **Black walnut, beech,** and **maple** are used to some extent. Black walnut is stronger than cherry, but, like beech and maple, is likely to warp.

It may be stated then, that, in the United States, white pine is the material commonly employed for pattern making. Lumber 1 inch, 1¼ inches, and 1½ inches thick will be found convenient in the construction of such patterns as are most commonly called for It will be a great saving of time and labor, after the lumber has been carefully selected, to have it taken to the planing mill and dressed on two sides to the following thicknesses:

One-inch, dressed on two sides to	⅞ inch;
One and one-quarter-inch, dressed on two sides to	1⅛ inch;
One and one-half-inch, dressed on two sides to	1⅜ inch;

and, if such can be found well seasoned, a small quantity of two-inch, dressed to 1¾ inches.

In addition to these sizes there should be a moderate amount of 1-inch resawed and dressed to $\frac{3}{8}$ inch or to $\frac{5}{16}$ inch; and the same amount of $1\frac{1}{4}$-inch resawed and dressed to $\frac{1}{2}$ inch. The two last thicknesses are used for gluing and building up the rims of pulleys, gear wheels, and other light work where strength and durability are required.

Warping and Twisting of Wood. Observation shows that if one side of a board is kept damp and the other dried, the former will expand so that the plank, although originally straight, becomes curved as in Fig. 1. Or if one side of a board is exposed to the air, while the other is more or less protected, as in the stack of boards shown in Fig. 2, the exposed side of the upper board will give off its moisture more rapidly than the other side, and the board will warp or bend in the direction shown by the dotted lines. The second board will also "draw" and to some extent follow the first, being in turn followed by the third, and so on until the entire stack is warped and bent.

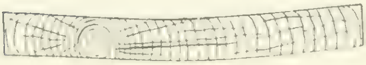


Fig. 1.

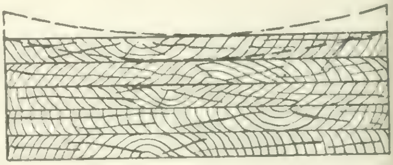


Fig. 2.

The same will be found true of a well-seasoned board if after being planed it is allowed to lie on its side on the work-bench. The upper side will give off its moisture more freely than is possible for the under side; the latter being protected and having its moisture retained by the bench. The lower side of the board is thus caused to expand, and the upper to contract, with the result that the board, although originally planed straight, becomes curved. For this reason all lumber, even if well-seasoned, should be so placed in racks, or on end, that the air may have free access to both sides of the planks; and newly planed boards, however dry and well seasoned, should never be stacked together, but so placed that both sides will be exposed alike.

This tendency to warp is explained to some extent by the porous nature of all woods, and their inclination to give off or to absorb moisture according to the condition of the surrounding atmosphere. As there is always more or less moisture in the air, and lumber of all kinds contains an amount of moisture which is ever changing according to the conditions of the surrounding atmosphere; this causes corresponding expansion or contraction of the wood.

Even under cover and in a dry place, wood has a tendency to warp on account of the greater shrinkage of the newer as compared with the older cells of the wood tissue or fiber in the side of the board nearest to the outside or sap wood of the tree. The inner side A of the board (Fig. 3) being closer to the heart wood, is older than the side B; its cells are firmer and more compact than those of B. As the board seasons, the newer and more open cells of the side B will shrink faster and to a greater extent than those of A, thus causing the board to draw or warp in the direction indicated by the dotted lines.

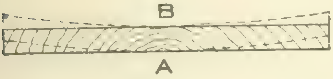


Fig. 3.

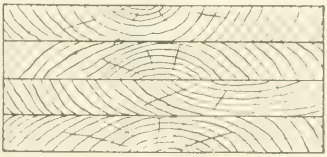


Fig. 4.

In gluing or building up stock for a pattern, this tendency may be corrected to some extent, by reversing the grain of the pieces that are to be glued, and placing two outsides (as B, Fig. 3) or two insides (as A, Fig. 3) together This is fully illustrated in Fig. 4.

In gluing very thin pieces together for the webs or centers of pulleys and for other purposes, it is often necessary to reverse the grain of the pieces, or to place the grain of *one piece at right angles to that of the other*, for the purpose of gaining greater strength and stiffness. In such cases, if only two thin pieces are used, the result, after they have been glued and dried, will be to some extent as shown in Fig. 5, the shrinkage and strain of the end grain crosswise of the board at *a*, being sufficient to bend the opposing thin board lengthwise of the grain at *b*, while on the side *cd*, the curve will be reversed for the same reason. *Whenever it is necessary to cross the grain of thin pieces for a pattern, three or more pieces should be used*, which will give satisfactory results if placed together as shown in Fig. 6.

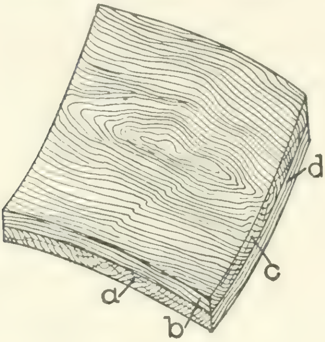


Fig. 5.

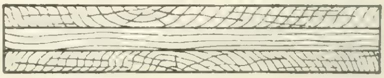


Fig. 6.

When thin circular disks of large size are to be glued up for patterns of any kind, the strongest, stiffest, and most satisfactory results will be obtained if the pieces are fitted and glued tangentially to the hub or other center or opening in the disk, as shown in Fig. 7. The grain of the wood must run lengthwise, and parallel to the longest side of each sector; and, after the pieces have been fitted together, a thin groove is cut in the edge of each, in which thin tongues of wood are inserted and glued, as illustrated in Fig. 8. Two disks are glued up, and one is turned over so as to reverse the grain of the sectors of one disk on that of the other, as shown by the dotted lines. The disks are then glued together, making a very rigid construction, and one which, owing to the continual change in the direction of the grain, will not warp.

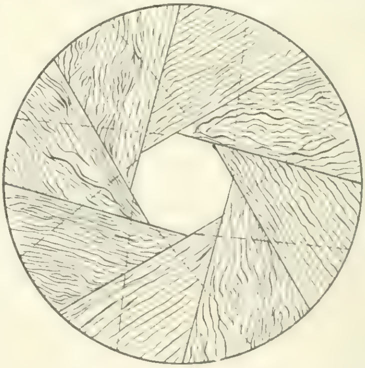


Fig. 7.

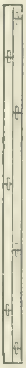


Fig. 8.

Should a wide and thin piece of a single thickness be required for a pattern, the board from which it is to be made should be ripped into strips of two, three, or four inches in width (according to the width of the required board), and the strips glued together again with each alternate strip reversed, as shown in Fig. 9. In this way the tendency to warp is to a great extent corrected, each narrow strip being inclined to warp in an opposite direction to that of its neighbor.

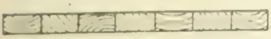


Fig. 9.

TOOLS.

While many of the tools used by the pattern maker are identical with those used by the carpenter and cabinet maker, yet the conditions that govern the construction of patterns for the molding of metals, together with the required accuracy in dimensions and the methods of construction used to guard against warping, distortion, and breaking, have very little in common with the workmanship and methods of the carpenter, the wood turner or the cabinet maker.

Following is a descriptive list of the more essential tools used in pattern making, accompanied with instructions in their use.

HAND SAWS.

Rip Saw and Crosscut Saw. Hand saws are of two kinds—**rip** and **crosscut.** The former, as the name indicates, is for cutting *with* the grain, or lengthwise of the board to be sawed. In Fig. 10 is illustrated a rip saw having 5½ points to the inch, which will work rapidly and with ease in pine and other soft woods. If mahogany, cherry, or other hard wood is to be ripped, a six-point saw should be used. Rip saws should be filed with all the bevel on the back of the tooth, as shown at *b* in Fig. 10, the front or "throat" of the tooth being at right angles to, or "square" with, the tooth edge of the blade, as at *a* in the same figure. The position of the line *cd*, whether perpendicular or slanting, is called the "hook" or "pitch" of the tooth.

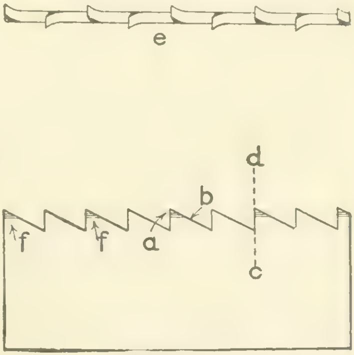


Fig. 10.

Rip saws should be filed square across; that is, the file should be held horizontal and at right angles to the side of the blade, always filing each alternate tooth from the opposite side of the saw; this, if done by beginning at the heel and working the file toward the point of the blade, will give a very slight bevel to the back edge of the tooth, causing it to cut cleaner and with less set than if filed otherwise.

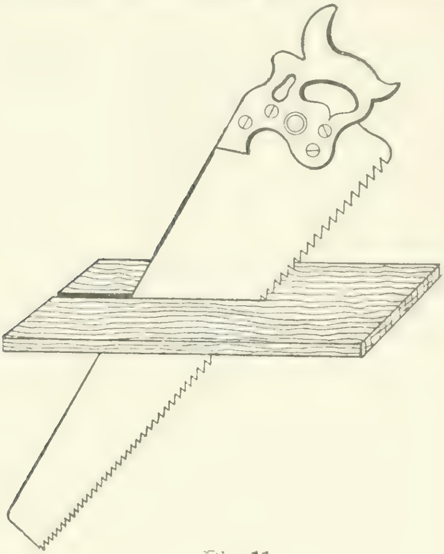


Fig. 11.

Rip saws require very little set for use in dry, well-seasoned lumber, such as is always used in pattern making. The teeth should be "set," or bent, only at the points, as shown at *e* and *f* in Fig. 10; and in no case should the set exceed more than half the depth of the tooth.

When the points only are set, the saw will work more freely, and the blade of the saw will not be "sprung," or bent, in setting. In using a rip saw, the front or cutting edge of the saw blade should be held at an angle of about 45° to the board, as shown in Fig. 11. This brings the back of the tooth nearly at right angles to the fibres of the wood, and insures a shearing cut. For fine work and well-seasoned material, hand saws may be bought ground so thin on the back as to require no set. Such tools work very smoothly and easily, cutting away less wood and doing better work than saws that have been set.

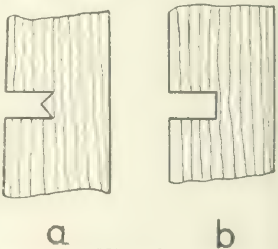


Fig. 12.

The crosscut saw really severs or cuts the fibres of the wood twice, as shown at *a* in Fig. 12, the intervening projections being loosened and carried out as dust by the thrust of the saw, producing a nearly straight-bottomed kerf, as shown at *b* (Fig. 12).

A crosscut saw for ordinary work should have five or six points to the inch; but for fine work ten or twelve points would be better, especially for dry woods, either soft or hard.

A section of a 6-point crosscut saw is shown in Fig. 13, and one of an 13½-point in Fig. 14.

In considering rip saws we find that the rake or bevel is all on the back of the tooth. In crosscut saws the rake is on the side of the tooth, as shown at *a* (Fig. 13.) In ripping, the point of the tooth acts as a chisel, cutting off the fibers of the wood, each tooth chiseling off a shaving as it passes through the board; but in crosscutting, the side of the tooth does the cutting, and therefore must have its bevel on the side.

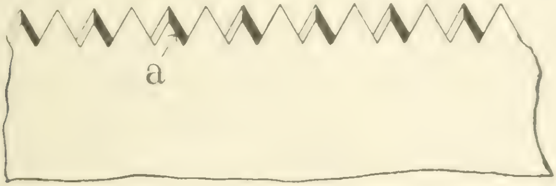


Fig. 13.

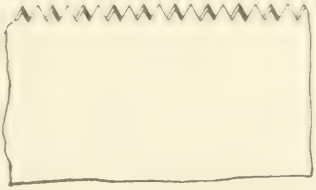


Fig. 14.

In Fig. 13 the bevel or **fleam** of the tooth is about 45°, and, as shown, there is no hook or pitch, the angle being the same on both the front and back of the tooth. This form of tooth works well in wet or in very soft wood; but for wood that is well seasoned, and for all the harder and firmer woods, the pitch of the front of the tooth should be at an angle of about 60° to the tooth edge of the blade, as shown in Fig. 15, and at *b* in Fig. 16. The amount of pitch in the teeth of a saw may be varied as demanded for different purposes or for different woods, but in all cases should be such as

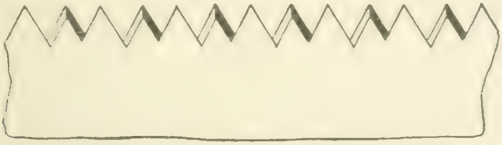


Fig. 15.

to loosen and carry out the intervening wood. Otherwise this would have to be rasped or filed out by the continued action of the saw.

The fleam of the side of the crosscut saw tooth is very important. When filing, the file should be held horizontally and at an angle of about 45° to the side of the saw, lengthwise of the blade, as illustrated in Fig. 16; and each alternate tooth must be filed from the opposite side of the blade, beginning at the heel and filing toward the point of the saw.

The objection is often raised by saw filers, that in filing from the handle end of the saw toward the point, a feather edge is made by the file and turned backward on the point of the tooth. The first thrust of the saw through the board, however, will remove this feather edge entirely; whereas, if the filing be done from the point of the saw toward the handle, it is necessary to file the teeth bent toward the operator, which causes the saw to vibrate, or "chatter;" and this not only renders good, even filing impossible, but breaks the teeth of the file.

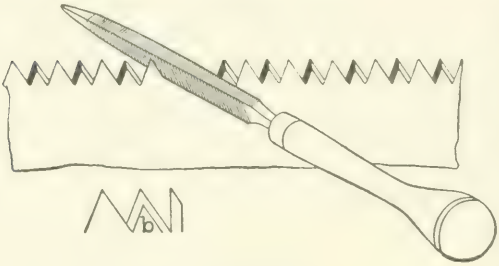


Fig. 16.

For hand and back saws, a saw-set that acts on the principle of the hammer and anvil, such as the one illustrated in Fig. 17, is best. The spring sets, so much in use, will not give so regular and even a set to the teeth as will one or more light blows with the hammer on the beveled face of the anvil. By this method the tooth is not bent or sprung beyond the position in which it is intended to remain, and the blade of the saw is not bent or affected by the stroke of the hammer on the point of the tooth. A saw-set of the kind illustrated in Fig. 17 can be adjusted to set the points of the teeth to any depth desired; and, even if repeated light blows are given, the tooth cannot be bent beyond the required distance. The blow may be struck on *a* with a light mallet; or it may be struck from below with the operator's foot on a treadle connected with *a*, leaving both hands free to hold and to guide the saw.

In setting a saw, it is always better to use two or three light blows on a tooth than to try to do the work with one heavy blow; and this is especially the case if the saw is hard, as all good and well-tempered saws should be.

The **back saw** illustrated in Fig. 18 is used as a bench saw for light or fine work, and for fitting and dovetailing. Saws of this type are made from 8 to 14 inches in length, the 10- and 12-inch being convenient sizes for general work. As the metal back holds and stiffens the saw, a thin blade should always be selected; and the methods of filing, jointing and setting are the same as already described for hand saws. At least two back saws will be found necessary, one filed for crosscutting, and the other filed as a rip saw for cutting *with* the grain of the wood, as in the cutting of tenons and dovetails.

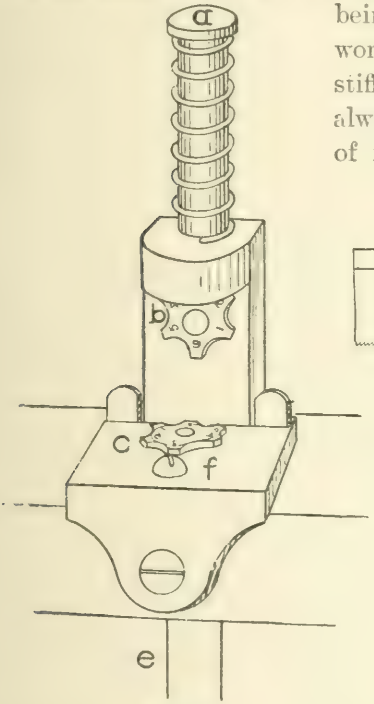


Fig. 17.

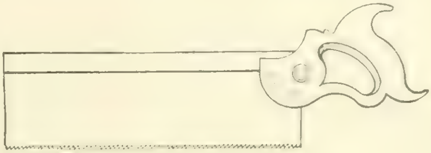


Fig. 18.

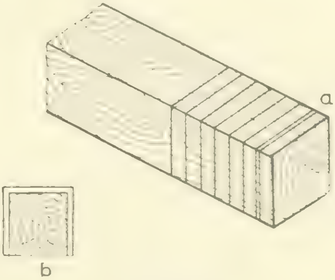


Fig. 19.

EXERCISE.

While for those who have had experience in carpentry the following exercise in the use of the back saw may not be necessary, it is recommended to all beginners who wish to acquire skill in the use of this important tool.

Take any block of wood from 12 inches to 16 inches long, about 2 inches wide, and about 1¾ inches in thickness. With try-square and a sharp-pointed pocketknife, lay it out as illustrated in Fig. 19, on the upper, front, and back sides of the block. The knife-cuts must be at least $\frac{1}{32}$ inch deep, and about ¼ inch distant from each other. Next proceed to saw up the block into thin sections, sawing each time so that the saw kerf will be just outside of, but close to the knife line, as indicated at *a*.

The saw-cut through the block should be true to each of the three lines; and while the saw passes along one side of the line, its teeth should not scratch the opposite side of the knife-cut, but should leave a smooth, clean angle of the knife cut on the block, as shown at *b* in Fig. 19, while at the same time it should be so close to the line as to leave no wood to be smoothed off with plane or chisel.

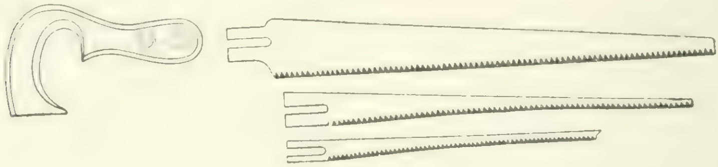


Fig. 20.

A few hours' thorough and careful practice of this exercise will enable any one to use the saw successfully.

Compass Saw. As the work of the compass saw, illustrated in Fig. 20, will be both *with* and *across* the grain of the wood, the best form of tooth will be that shown in Fig. 21, having more pitch, and slightly less bevel, than the crosscut saw. A crosscut saw will rip better than a rip saw will crosscut; hence the shape of tooth should be between the two. Compass saws are ground very thin on the back of the blade, but in order to turn easily they should be set the same as hand saws. And here we wish to impress on the beginner the necessity of keeping his saw and indeed all other cutting tools perfectly sharp and in good working condition at all times. A sharp saw will work faster, and will always do smoother and better work with less set and with less expenditure of power, than a dull one. Even to saw well is an art, which cannot be gained through the use of dull, imperfectly set, and poorly kept tools. To file well will require from the beginner close attention, a study of the subject, and careful practice, all of which

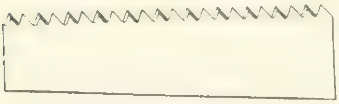


Fig. 21.

can be given by any one possessing ordinary mechanical ability. If the filing is done slowly at first, care being taken to hold the file at the same angle for all the teeth, a little faithful practice will always bring success.

PLANES.

The Iron Plane. The modern iron plane, illustrated in Fig. 22, can now be bought in a great variety of sizes and styles. These planes, with their true and unchanging faces, and their simple appliances for setting and adjusting the cutter (or **plane-iron**) to the face of the plane and to the required thickness of shavings, are greatly to be preferred to the old-style wooden planes.

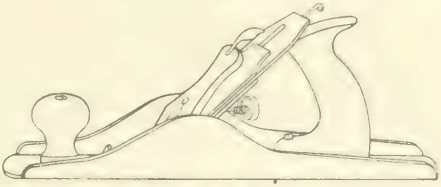


Fig. 22.

The general construction of the iron plane will be readily understood from Fig. 23, one side of the plane being removed to show the arrangement of the parts; *a* is the cutter, or plane-iron, which is made of the best cast steel and of equal thickness throughout. In all new planes this part will be found ground and sharpened for immediate use.

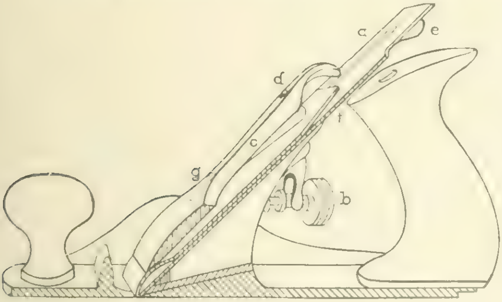


Fig. 23.

The cap-iron *f* (Fig. 23) is fastened to the plane-iron, by an adjusting screw, as shown in Fig. 24. For whetting or grinding the cutting edge, it is not necessary to remove the cap-iron,

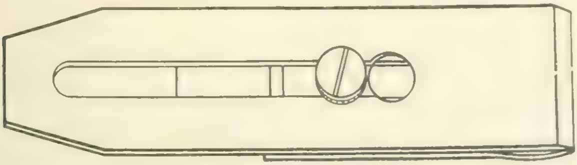


Fig. 24.

but only to loosen the connecting screw and to slide the cap back to the extreme end of the slot in the plane-iron, tightening it there by a turn of the screw. The cap-iron will then serve as a convenient handle or rest in whetting or in grinding.

The iron lever *e* (Fig. 23) is held in place below its center by the screw *g*, which acts as a fulcrum, and the lever is readily clamped down upon the irons by the use of the cam-piece *d*. When this cam is turned upward it ceases to bear upon the irons. The lever *e* may then be removed from its place, and the irons released, without turning or changing the adjustment of the screw *g*, as the lever and irons are properly slotted for this purpose.

Should the pressure required for the best working of the plane-iron need changing, it can easily be obtained by tightening or loosening the screw *g*.

When the plane-iron is secured in its place, the use of the brass thumb-screw *b* will *draw* or *drive* the plane-iron; and thus the thickness of the shaving to be taken from the work can be regulated with perfect accuracy. By the use of the lever *e*, located under the plane-iron, and working sidewise, the cutting edge can easily be brought into position exactly parallel with the face of the plane, should any variation exist when the iron is clamped down. To ascertain this, hold the plane up, and look down over its face; the greater projection, if there be any, of one or the other of the corners of the iron, can readily be seen.

The cap-iron *f*, which is not sharp, is *not*, as is often supposed, used for the purpose of strengthening or stiffening the cutting iron, but as a chip-break to prevent the cutting edge of the plane-iron from chipping, tearing, and breaking the grain of the wood below the surface when the grain turns and twists, or when it is knotty and crooked. In such cases the tendency of the plane-iron is to split and tear out the fibres of the wood in front of the cutting edge. To avoid this, the cap-iron is screwed on with its dull edge quite close to the cutting edge, so as to bend and break off the fibres or the shavings before the split gets fairly started below the surface.

The cutting edge of the plane-iron is said to have *lead* in proportion to the distance it is placed in advance of the dull edge of the cap-iron. The depth of the splits, or the roughness of the cross-grained surface, will be just equal to the lead of the cutting edge. For soft, straight-grained wood, the lead may be $\frac{1}{32}$ inch or even more, but this must be reduced in proportion as the wood is curly, cross-grained, or knotty.

The grinding, or the whetting, must always be done on the *bevel* side only of the plane-iron, the upper side being kept as flat and as smooth as possible to secure easy working.

All plane-irons should be ground slightly rounding to the extent of the thickness of a thin shaving. This rounding of the cutting edge should be the true arc of a circle throughout the entire length of the cutting edge, and not simply a rounding-off of the corners as is sometimes directed. Rounding the edge to the extent of the thickness of a shaving will prevent the plane-iron from grooving into, or plowing out a wide groove in, the surface that is being worked, and will also assist greatly in working the edges of the piece to right angles, or square with the face side. To do this it is not necessary, should one corner of the edge be higher than the other, to tilt the plane on the high edge, but, while holding it flat and firm on the surface of the edge being planed, push the plane sidewise towards the highest corner in order to reduce that corner. This will readily be understood when we remember that the cutting edge of the iron is rounding. If the plane is held so that the middle of the plane-iron will do the cutting, the shaving planed will be of the same thickness on both edges; but if the plane is pushed over to one side, either to the right or to the left, the shaving will be feather-edged, or thick on one edge and thin on the other, thus reducing the higher corner of the edge of the piece.

When the plane is to be used, the beginner should first carefully adjust it to the thickness of shaving required, by holding it up and looking down over the face of the plane, when the projection of the plane-iron can readily be seen, and then by testing on the piece to be planed.

The operator's position should be one of perfect ease, standing well back of the piece to be planed, and pushing the plane to arm's length *from* (not alongside of) the operator, taking long and continued shavings from the board. When starting the shaving at the end of the board, care should be taken to hold the forward end of the plane down firmly, or the act of pushing it forward will cause that end to tilt up and the plane-iron to chatter on the surface as it begins to cut the shaving. This is owing to the fact that nearly two-thirds of the plane overhangs the end of the board, requiring firm pressure on the forward end to balance it while the stroke is being started.

To insure smooth work, care must be taken to plane *with the grain* of the wood, and not *against* the ends of the fibres as they lie in the surface of the board. Should the fibres tear out and the surface become rough, reverse the ends of the boards so as to cut the shaving in the opposite direction, and note the difference in the effect on the planed surface.

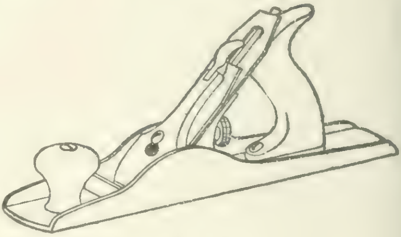


Fig. 25.

Of iron planes, the most important is the No. 5 **jack plane,** 14 inches long, and having a cutter 2 inches in width. This plane is illustrated in Fig. 25.

When the pattern lumber has first been roughly planed in a planing mill, this No. 5 plane almost exclusively can be used for planing and pattern making. In making or in "truing up" very large surfaces, however, or in making long glue joints, the No. 7 **jointer plane,** 22 inches long and having a cutter $2\frac{3}{8}$ inches wide, will be found necessary. This plane is shown in Fig. 22, and differs from the jack plane only in its length and in its extra width of face.

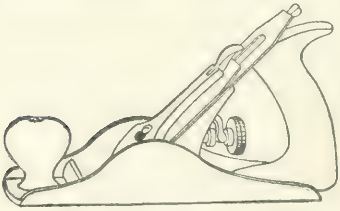
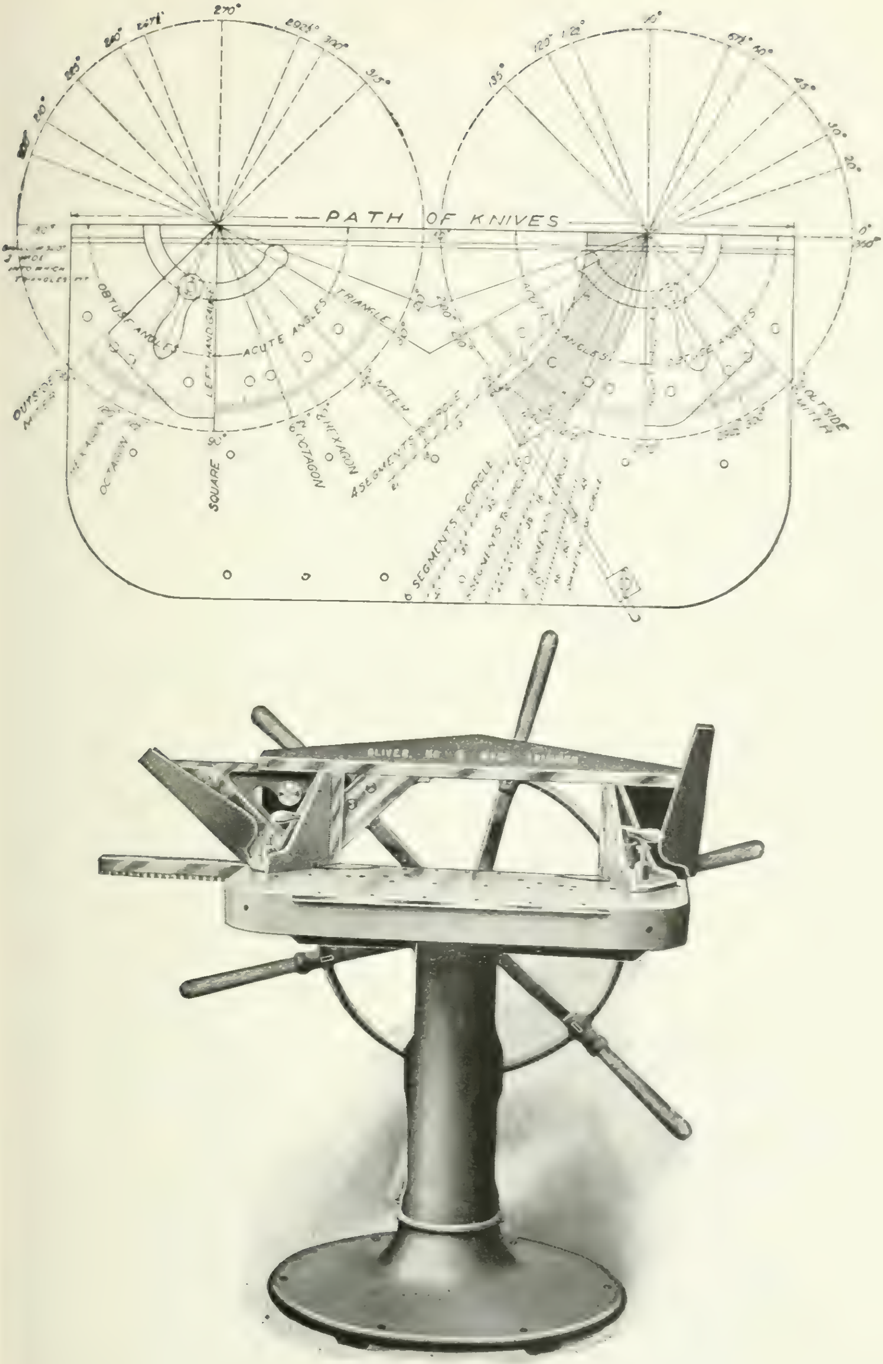


Fig. 26.

For mahogany or other hard wood, the No. 4 **smooth plane,** illustrated in Fig. 26, will be found very useful. This plane is made in several sizes. The No. 4, which is 9 inches long and has a 2-inch cutter, is the best size for general use.

Next in importance to the three planes already mentioned, is the **block plane,** illustrated in Fig. 27. The No. 19, which is 7 inches long and has a cutter $1\frac{3}{4}$ inches wide, is the most desirable for the pattern maker's use. It has an adjustable throat, as well as the screw and lateral lever adjustments of the other planes. This



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plane has the advantage of being so constructed as to be held easily in one hand. Owing to the low angle at which the cutter is placed it works more smoothly and easily on end wood and on miters than any other plane.

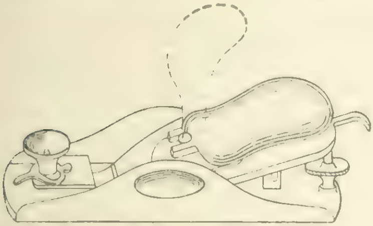


Fig. 27.

In cases where lumber must be dressed from the rough, without being first roughly dressed in a planing mill, the No. 40 **scrub plane,** illustrated in Fig. 28, will be almost indispensable. It is 9½ inches long, and has a cutter 1¼ inches wide. The cutter is a single iron, and is ground and sharpened very rounding on the cutting edge, as shown in Fig. 28, to allow of cutting a very thick shaving without grooving at the edges. This plane works rapidly and easily, preparing the rough-sawn surfaces of planks for the finishing planes.

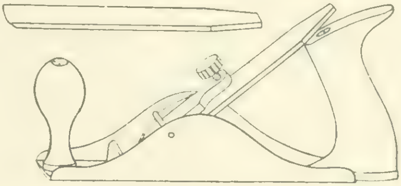


Fig. 28.

For truing and smoothing circular arcs and curves of all kinds, either convex or concave, there is no tool that equals the **circular plane,** illustrated in Fig. 29. This plane has a flexible steel face which can easily be shaped to any required arc or curve by turning the knob on the front of the plane.

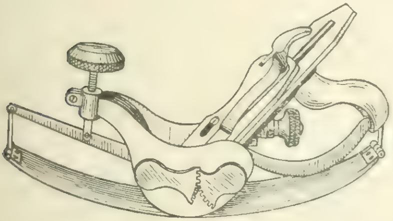


Fig. 29.

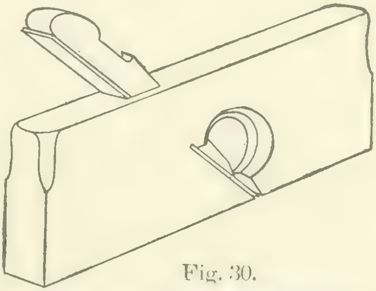


Fig. 30.

The Rabbet Plane. Among the special planes used by the pattern maker, the rabbet plane, illustrated in Fig. 30, is the most important. The face of this plane is always flat and at right angles to the sides. It is used in working out square angles and corners, or *laps* as they are called in carpentry, and also for working lap joints, as shown in Fig. 31.

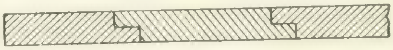


Fig. 31.

The skew-iron rabbet plane, in which the cutting edge of the plane-iron is set diagonally across the face of the plane, works much more smoothly and easily than one in which the iron is set at right angles to the side of the plane. The improved rabbet plane shown in Fig. 32 is fitted with depth gauge, and also with a spur cutter, both of which are often of great convenience to the workman.

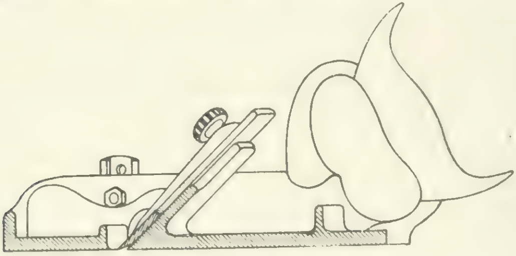


Fig. 32.

Rabbet planes are made in sizes ranging from $\frac{1}{2}$ inch to $1\frac{1}{2}$ inches in width. The 1-inch and $1\frac{1}{4}$-inch are convenient sizes for general work.

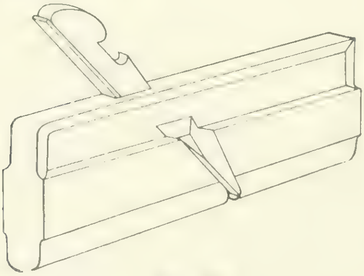


Fig. 33.

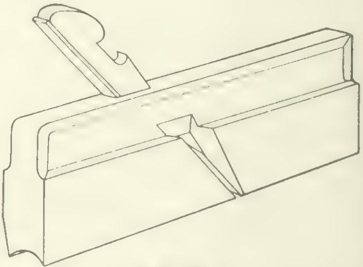


Fig. 34.

Round and Hollow Planes. These planes are illustrated in Figs. 33 and 34. They are made of different curvatures, and a set of assorted sizes, especially the *rounds*, are almost indispensable to the pattern maker for finishing semicircular core boxes, for making fillets, and for working out curves of every description, both concave and convex.

The Core-Box Plane. The core-box plane, shown in Fig. 35, while not indispensable, will be found to be a very rapid working and useful tool for making semicircular core boxes up to 2½ inches in diameter. By using the extension sides, one of which is shown in the illustration, and two pairs of which are always furnished, this tool will work accurately a concave semicircle up to 10 inches in diameter.

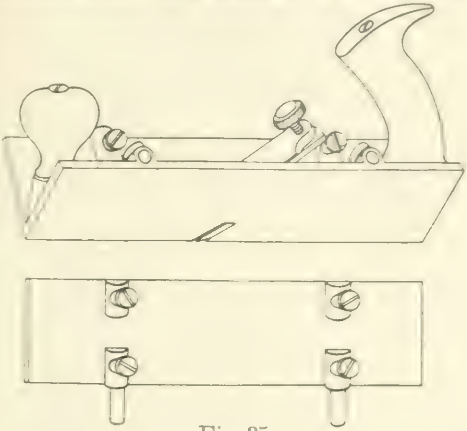


Fig. 35.

The core-box plane is constructed upon the principle that if the sides of a right angle lie upon the extremities of a diameter of a circle, the vertex of the right angle will lie upon the circumference of the circle. This is illustrated in Fig. 36, from which it will be seen that if the block of wood has been worked to a perfect semicircle, and the edges of the blades of a try-square or right-angled triangle touch the semicircular curve at its extremities, the right angle or corner will touch the arc at some point, as *b*, *e* or *h*, the angles *abc*, *def*, and *ghi* all being right angles.

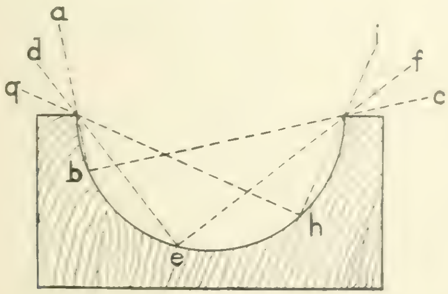


Fig. 36.

To this kind of plane the objection is often made that it abrades and wears off the corners of the semicircle as it is being worked out. This, however, can be practically avoided if the following instructions are followed:

Carefully lay out the block from which the core box is to be worked, from a center line on the face of the block, describing on each end of the block a semicircle of the required radius; connect the extremes of the two end arcs by straight lines on the face of the block, as shown in Fig. 37. Two very thin strips of hard wood are tacked along these lines, just outside of the wood to be cut away, as shown at *a* and at *b* in Fig. 38. These strips form rests for the sides of the plane while the heavier part of the work is being done. After working out the semicircle as far as the strips will allow, as shown by the dotted arc *acb*, the strips are removed, when the work can be finished without materially affecting the corners at *a* and *b*.

When making the finishing cuts with this plane, care must be taken to adjust the cutter centrally, *i. e.*, so that it will cut equally to both right and left; otherwise the work will not be correct. If, however, the work has been done with care, the finishing may be completed with coarse, and lastly with fine, sandpaper held on a cylindrical block of radius slightly less than that of the required core box.

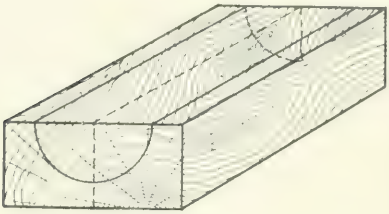


Fig. 37.

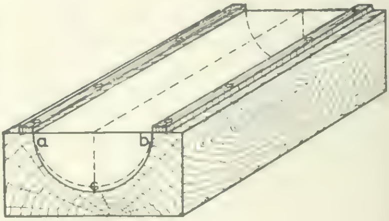


Fig. 38.

The Router Plane. This tool will be found very convenient for smoothing out sunk panels, for letting in rapping and lifting plates, and for all depressions below the general surface of the pattern. It will plane the bottoms of recesses to a uniform depth from the surface of the work, and will work into angles and corners that otherwise could be reached only by the use of the paring chisel. It is illustrated in Fig. 39.

The Spoke-Shave. The spoke-shave is used by the pattern maker for shaping and rounding out small curves either convex or concave, which cannot be reached with the circular plane. It can be found in a great variety of styles, either in metal, as shown in Fig. 40, or in wood. The all-wood boxwood spoke shave illustrated in Fig. 41, without brass facing or screw adjustment, is to be preferred to all others for the pattern maker's use, especially for working pine or other soft wood.

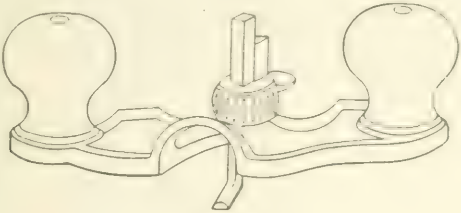


Fig. 39.

CHISELS AND GOUGES.

The chisel enters so largely into the work of the pattern maker in paring and shaping patterns that the quality of the tool should

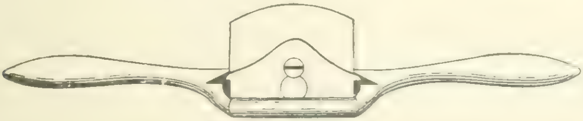


Fig. 40.

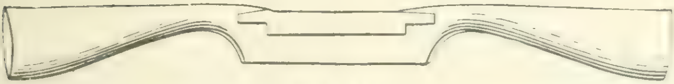


Fig. 41.

be of the best. While carpenters' chisels are made in several styles, they may be divided into two general classes, **socket-handled chisels,** and **firmer** or **paring chisels.** The former are illustrated

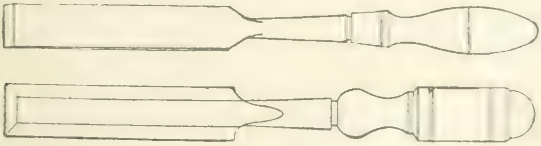


Fig. 42.

in Fig. 42, and are used for framing, and for very heavy work of all kinds in which the use of a mallet is necessary. The common firmer or paring chisels, two styles of which are shown in Fig. 43, are the best all-round chisels for pattern work. Being lighter and thinner than the others, they are better adapted to the light work on which they are used; moreover, when used with care, they will answer every desired purpose, even for heavy work or with a mallet.

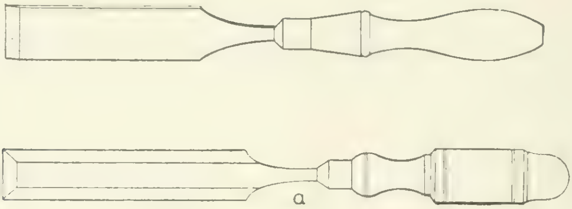


Fig. 43.

The beveled-edge chisel shown at *a*, Fig. 43, is greatly to be preferred. It is lighter than the other kind illustrated, and the square angle being removed, the workman is enabled to reach into angles and under projections difficult to reach with a square-edged tool. A set varying in width from ⅛ inch to ⅝ inch by eighths, and from ¾ inch to 1½ inches by quarters, nine chisels in all, will be found useful.

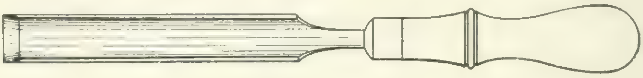


Fig. 44.

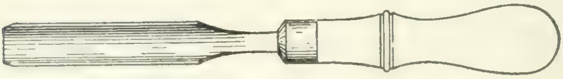


Fig. 45.

The paring gouges used in pattern making are ground or beveled on the inside, as shown in Fig. 44. These gouges are made in **regular**, **middle**, and **flat** sweeps. They are indispensable for working out core boxes and other curves.

In selecting a set of paring gouges, they should be not only of assorted sizes, but of different sweeps, so as to work out semicircles and curves of different radii

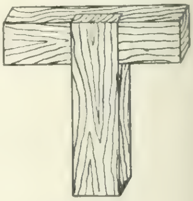


Fig. 47.

The common firmer gouge, illustrated in Fig. 45, is a useful tool for rough or heavy work, but in general its use can be dispensed with in pattern making.

The manner in which the chisel is used is so obvious and simple that any instruction in that direction would seem unnecessary. We shall only say in a general way that in using a chisel on a flat surface or in a recess it should always be held with the flat or back of the chisel against the work; and, whenever possible, it should not be pushed straight forward or straight through an opening, especially when paring across the grain of the wood, but should be moved laterally at the same time that it is pushed forward, as indicated by the dotted lines in Fig. 46. This insures a shearing cut, which, with care, even when the material is cross-grained, will produce a smooth and even surface.

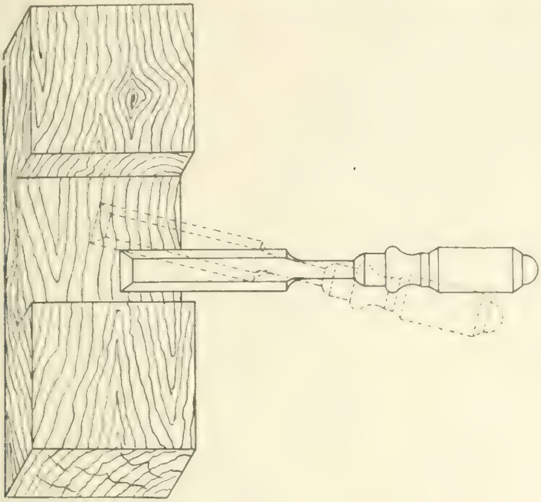


Fig. 46.

As an exercise for acquiring the free use of the paring chisel, there is nothing better for the beginner than the simple half-lap joint shown in Fig. 47.

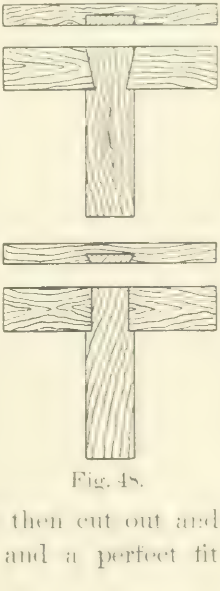


Fig. 48.

The shoulders or the ends of the openings must be cut with a back saw. The opening is then cut out and the shoulders smoothed with a wide chisel, and a perfect fit obtained by continued trials.

The two dove-tail joints shown in Fig. 48 may be attempted, after having succeeded with the half-lap; and these exercises should be continued by the student until such control of the chisel is attained that this and similar work can be done with ease and certainty. For laying out work of this kind the blade of a pocketknife or bench knife should always be used. This gives a clean, sharp-cut angle for the meeting sides of the joints, which cannot be obtained if a scratch-awl is used. The awl tears and breaks the fibres of the wood, producing a rough, ragged angle, which, on fitting, cannot produce a smooth and close piece of work. A pencil is equally objectionable because of the indefinite dimensions given by its use.

An assortment of four to nine carver's gouges, **front bent** as shown in Fig. 49, will be found necessary for working out short, deep curves, and in places where a straight gouge cannot be used, as in the core boxes for a globe valve, shown in Figs. 222, 223, 227, 228, and similar work.

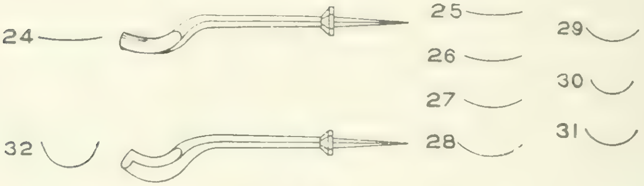


Fig. 49.

The full set consists of *nine* tools, the curves of which are numbered from 24 to 32. The two extremes, Nos. 24 and 32, are shown in Fig. 49, and also the shapes of the curves of the seven intermediates, Nos. 25 to 31 inclusive.

If desired, to save expense, each alternate tool might be omitted from the set, only the odd numbers 25, 27, 29 and 31 being selected. For ordinary work these will be found sufficient.

SQUARES.

The best try-squares are now made with graduated blades, Fig. 50, and from two inches to twelve inches in length of blade. Several sizes will be found necessary, as in many cases the blade must be short to admit of its application in pattern work.

The adjustable try-square, illustrated in Fig. 51, is not expensive, and will be found to fill the requirements of several small squares. It is made in two sizes, with graduated blades four inches and six inches in length respectively. The blade of this square can be firmly secured in its seat at any point. When the blade is carried entirely to the front of the handle, it is like an ordinary try-square; and the moving of the blade makes the square equally perfect down to one-quarter-inch length of blade, or even less.

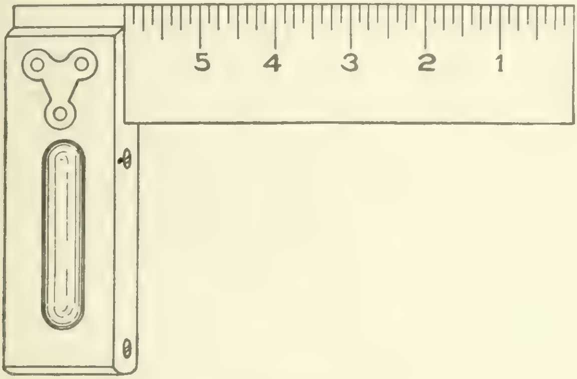


Fig. 50.

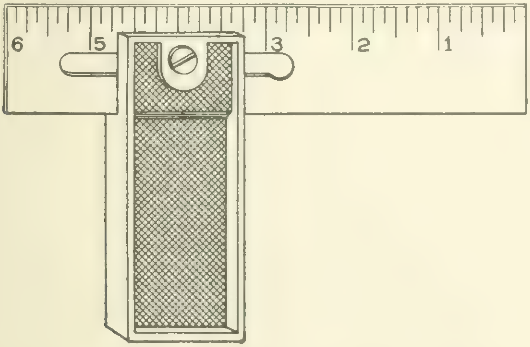


Fig. 51.

With one adjustable square of this kind, six inches in length, only one 8-inch or one 10-inch ordinary square will be found necessary.

A still more convenient, but slightly more expensive, form of adjustable try-square is shown in Fig. 52. It differs from that shown in Fig. 51, in being self-contained, no screw-driver being necessary for moving the blade or securing it in position, and also because the blade can be removed entirely, and an extra blade, shown in Fig. 53, substituted. The ends of this second blade give both the hexagon and octagon angles, which is a matter of great convenience to the pattern maker. Fig. 53 shows the hexagon end of the blade applied. Reverse the blade and the octagon end will be in position for use.

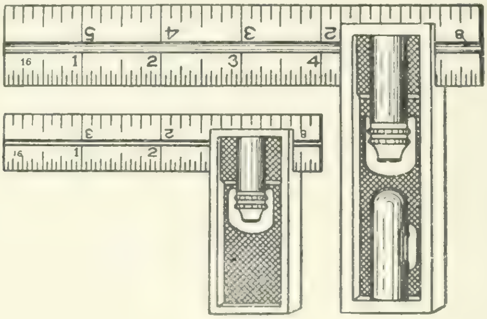


Fig. 52.

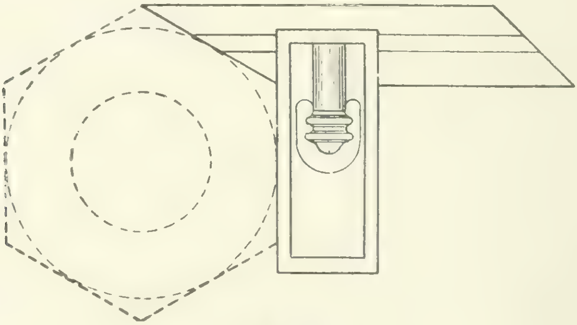


Fig. 53.

To the above try-squares there should be added a carpenter's steel square 24 inches × 18 inches, for use in laying out and squaring up large stock and large patterns.

BEVELS.

The bevel illustrated in Fig. 54, with the clamping screw in the end of the handle, is the most accurate and the most easily adjusted style of this indispensable tool. The blades are made from 6 to 12 inches in length, and have a slot in one end, which admits of that end being shortened to meet the requirements of work.

The small **Universal bevel,** illustrated in Fig. 55, like the adjustable try-square, is not an expensive tool, and will be found generally useful, especially in working the draft on patterns, and in turning the parts of patterns on the wood lathe which cannot be reached with an ordinary bevel. The *set-off* in the blade increases its capacity and usefulness, so that any angle, however slight, can be obtained.

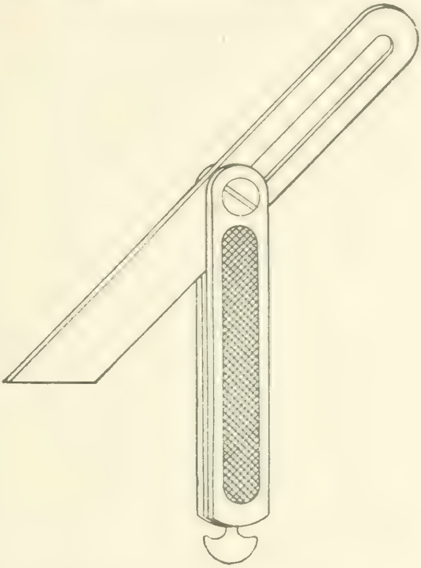


Fig. 54.

One 3-inch *Universal*, and one 8-inch or 10-inch ordinary bevel, will meet all the requirements of the pattern maker for the beveled edges and surfaces and the draft of pattern work.

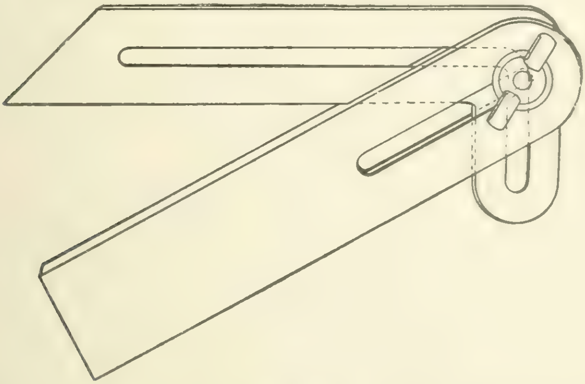


Fig. 55.

MARKING GAGES.

The marking gage is used for drawing a line at a given distance from, and parallel to, the already trued and jointed surface or edge of a board or piece of wood that is being marked to dimensions. There are many forms of this tool, but in the "Improved Marking Gage," illustrated in Fig. 56, the head is reversible. The flat side of the head is used for ordinary straight work, while the reverse side, having the brass face with two projecting ribs, enables the operator to run a gage line with perfect steadiness and accuracy around curves of any radius, either convex or concave —a feature much to be desired in a pattern-maker's gage.

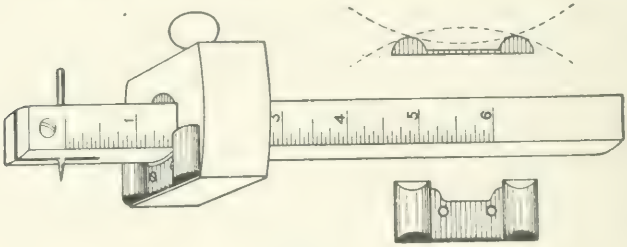


Fig. 56.

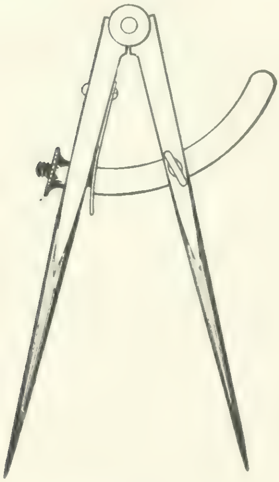


Fig. 57.

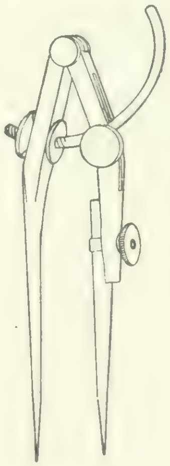


Fig. 58.

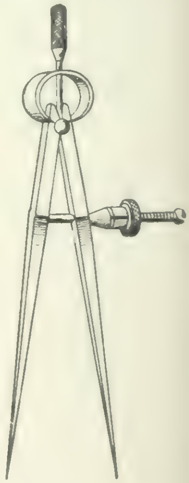


Fig. 59.

DIVIDERS AND TRAMMELS.

The ordinary wood-worker's dividers can be bought in many forms, the most common being the **screw-adjusting wing dividers**, shown in Fig. 57. This form is reliable, and is easily adjusted to the required distance between points. Moreover, when clamped by the thumb-screw, it is not liable to be altered by a slight blow in handling.

Another and improved form is shown in Fig. 58, one leg of which is removable so that a pencil can be inserted. This will be found very convenient for marking and laying out work.

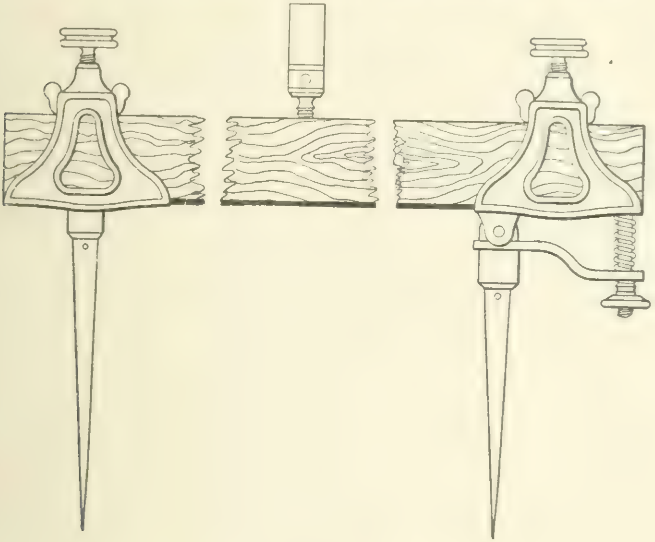


Fig. 60.

For spacing the teeth of gear wheels, and for other work in which great accuracy is required, a pair of 2½-inch or 3-inch dividers, such as are shown in Fig. 59, will be found necessary.

The **trammel** is used when the distance between the points to be reached is too great for the ordinary dividers. The trammel points are clamped to a beam of sufficient length to enable them to be set to the required distance apart. They may be bought with one adjustable point, as illustrated in Fig. 60; or without the screw adjustment, as in Fig. 61. The points are removable for the insertion of a pencil socket and pencil when needed.

For very accurate work, an excellent tool of this kind is illustrated in Fig. 62. The beams furnished are 4 inches and 13 inches in length. By the use of the cone center, shown at V, which may be substituted for the regular point, the tool can be used for scribing a line around any hole already bored—which is sometimes a matter of great convenience. The complete set includes the pen, pencil, straight and bent points, and the cone center, as shown in the cut.

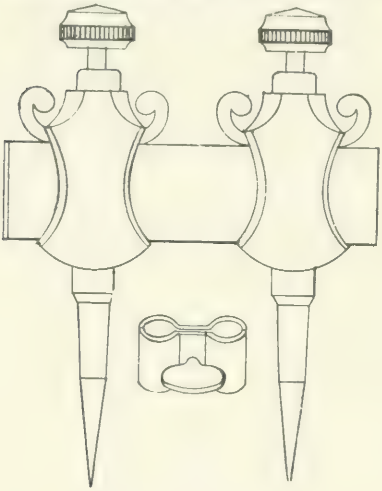


Fig. 61.

CALIPERS.

Calipers, like dividers, are made in many different forms, with and without screw adjustment. Fig. 63 illustrates the screw-adjusting wing calipers for outside measurements; and Fig. 64 the firm-joint outside calipers, used for the same purpose.

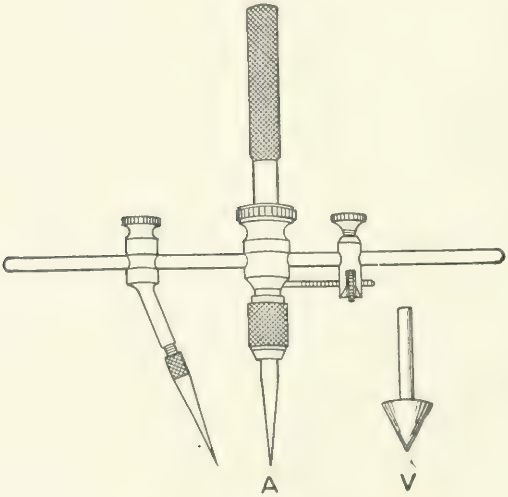


Fig. 62.

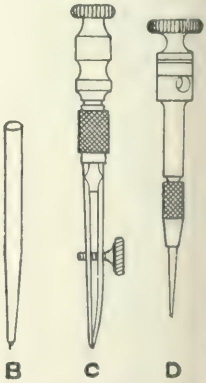


Fig. 62A.

Inside calipers for taking inside dimensions and inside distances are shown in Fig. 65.

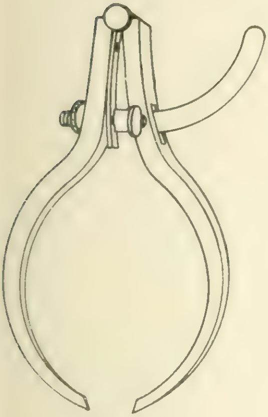


Fig. 63.

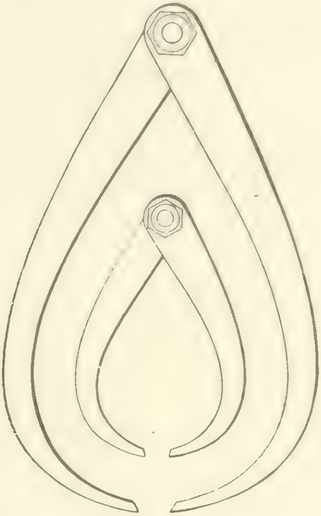


Fig. 64.

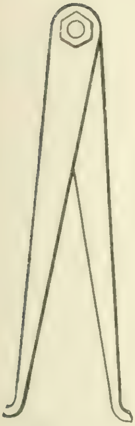


Fig. 65.

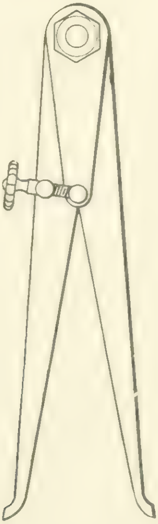


Fig. 66.

The adjustable inside calipers are illustrated in Fig. 66.

Calipers are used for measuring the distances between points external and internal, when a rule could not be used with accuracy.

They are indispensable to the wood turner for measuring the diameters of cylindrical forms and other work while being turned to required dimensions in the lathe. When used by the pattern maker, they may be applied while the wood is revolving, until it has been reduced almost to the required dimensions; after which, when the calipers are used, the lathe should be stopped, to prevent the surface from being marked by the points, and in order to obtain exact measurements.

The calipers should not be pushed or forced over the piece, but in passing over the finished cylinder, the points should touch it lightly without springing the legs of the calipers; otherwise the required dimensions cannot be obtained with accuracy.

MISCELLANEOUS TOOLS.

There remain to be described a few tools, which, while necessary, are so common as hardly to require either illustration or

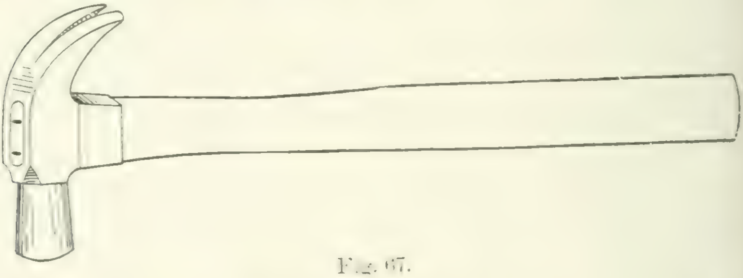


Fig. 67.

description. Among these are the **hammer**, the best form of which for the pattern maker is shown in Fig. 67, and the **mallet**, o which the best form is shown in Fig. 68.

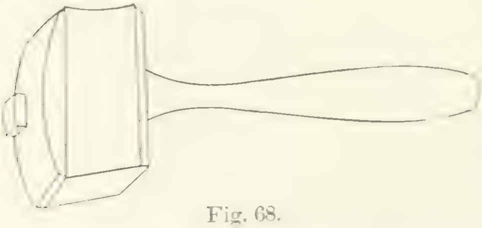
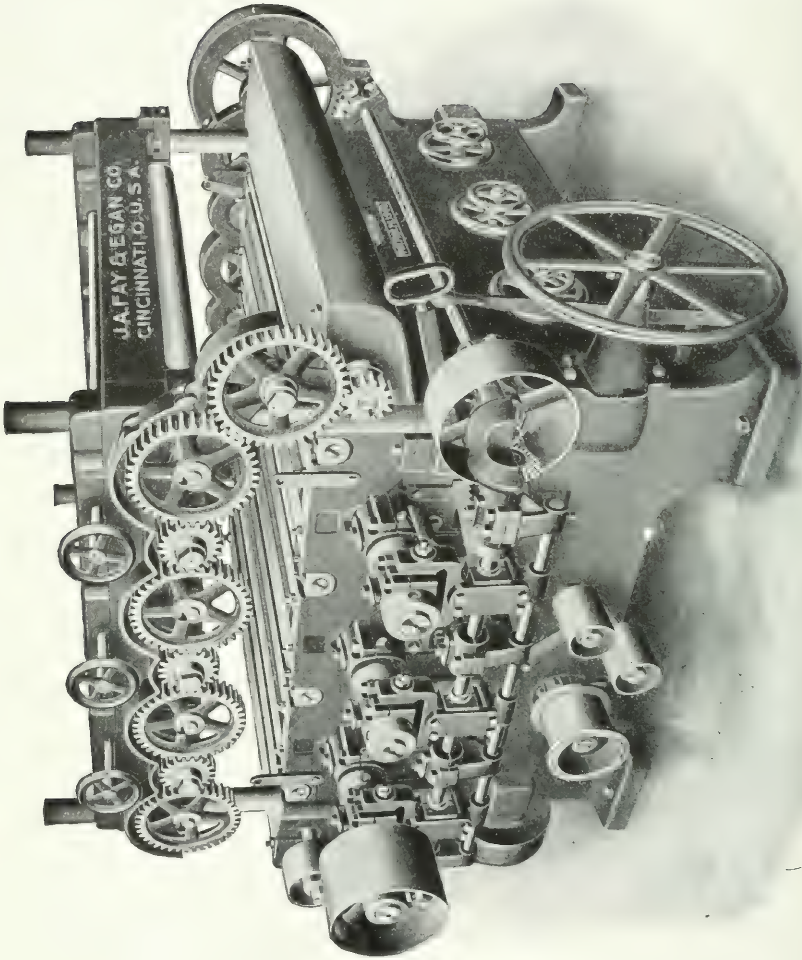


Fig. 68.

A mallet that is t be used on the handl of firmer chisels an other pattern maker tools, should not b made of hickory or lignum-vitæ, nor have hard-rubber or hard-fibre facing. Mallet thus made soon mar, splinter, and destroy the tool-handles


J.A.FAY & EGAN CO.
CINCINNATI, O. U.S.A.

which they are used. Beechwood and maple furnish the best material for mallet-heads for the use of the woodworker who works in pine and other soft woods. It is true that the mallet-head will not last so long if made of beech or maple wood; but the chisel and gouge handles will be protected, which is a matter of much greater importance.

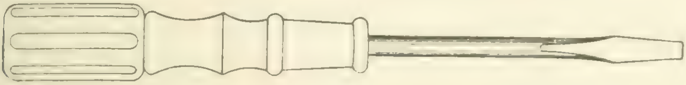


Fig. 69.

Of the **screw-driver,** illustrated in Fig. 69, at least two or three sizes will be found necessary.

The **scratch-awl,** Fig. 70, although used but little at the work-bench (a knife being used in its place for all accurate markings), is indispensable to the pattern maker for laying out the dimensions on his work while it is revolving in the turning lathe. It should be long and slender, as shown, and is used on the revolving wood by placing it over the required graduation of the rule, while the latter is held on the tool rest.

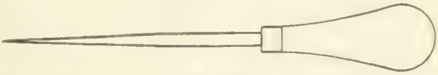


Fig. 70.

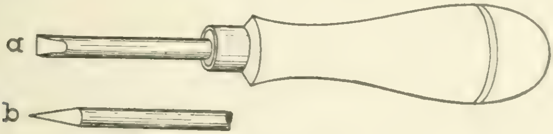


Fig. 71.

Brads and small wire nails must often be driven at such an angle to the grain of the wood, or in such a position, as to make it necessary first to bore a small hole in order to start the brad in the required direction. The brad-awl, illustrated in Fig. 71, is a convenient tool for this purpose. It is commonly ground to a chisel point, as shown at *a*, but will be less liable to cause splitting, and will work faster and with greater ease, if ground to a double spear point, as shown at *b*. The four corners, if kept sharp, will enter the wood and cut faster than the chisel point.

Side-cutting **pliers**, such as are illustrated in Fig. 72, will be found convenient not only for cutting off wire and brads, but for removing small brads and for holding small pieces while being worked to shape.

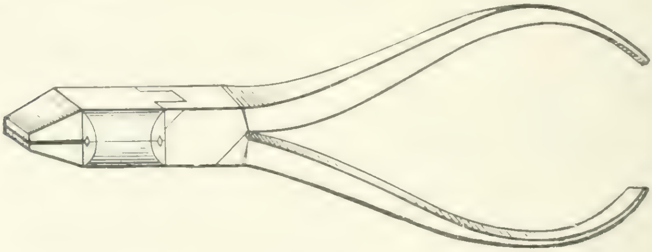


Fig. 72.

Among the tools which cannot be dispensed with are the **brace** and an assortment of **boring bits.** The most desirable style of brace is the **ratchet brace,** illustrated in Fig. 73. The convenience of the ratchet will soon be apparent from the necessity, so often arising, for boring holes or driving screws (with the brace) in angles or close to projections where the full sweep of the brace cannot be taken. Braces are made in many sizes, with sweep varying from 6 inches to 14 inches in diameter.

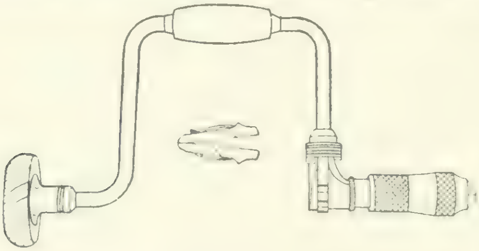


Fig. 73.

A brace with an 8-inch sweep is the most convenient in size for boring holes one inch or less in diameter in soft wood. For larger holes, and especially in very hard woods, a 10-inch or 12 inch sweep will be necessary.

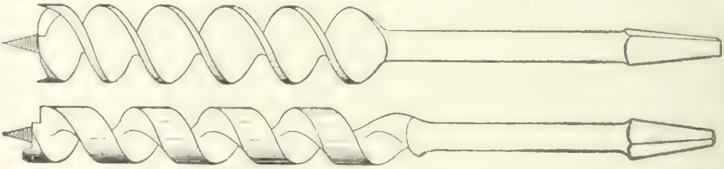


Fig. 74.

Wood-boring bits are made in many styles. The most important are the auger bits, two styles of which are shown in Fig. 74.

They can be bought in sizes running by sixteenths of an inch from ¼ inch to 1 inch. For holes larger than one inch, the **No. 2 extension bit,** shown in Fig. 75, is the best. It has two cutters, and will bore a hole of any size from ⅞ inch to 3 inches in diameter.

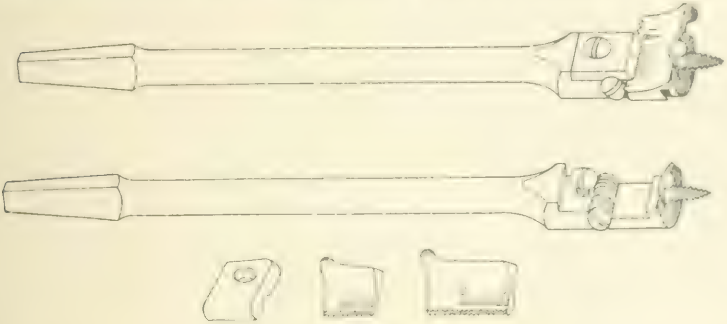


Fig. 75.

For screw-holes, the **gimlet bit** or the **twist drill** for wood, both of which are illustrated in Fig. 76, can be bought in all sizes running by thirty-seconds of an inch from $\frac{1}{32}$ inch up to ⅜ inch.

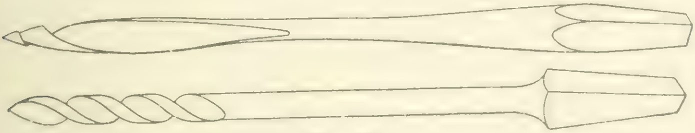


Fig. 76.

The **brace screw-driver,** and also the **brace countersink** for screw-heads, are important tools. They are shown in Fig. 77, and can be bought in large, medium, and small sizes.

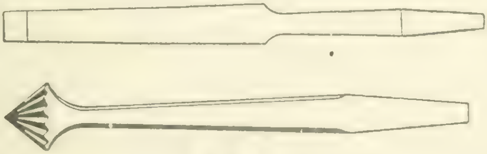


Fig. 77.

The half-round **cabinet file** and half-round **cabinet rasp,** shown in Fig. 78, enter largely into the work of the pattern maker, and should be bought in sizes each of 6 inches, 8 inches, and 10 inches. Larger as well as intermediate sizes may often be found necessary, but will not be needed for ordinary work.

Every pattern shop should have at least one dozen each of three or four different sizes of **hand screws** or **clamps** similar to that shown in Fig. 79. These are adjustable through wide ranges. They are used for clamping together the material that is being glued up to form the different parts of a pattern, and are convenient also for many other purposes. The all-iron C clamp, shown in Fig. 80, is sometimes useful in positions that are hard to reach with a hand-screw. The method of adjusting and of using the hand-screw will be fully explained later.

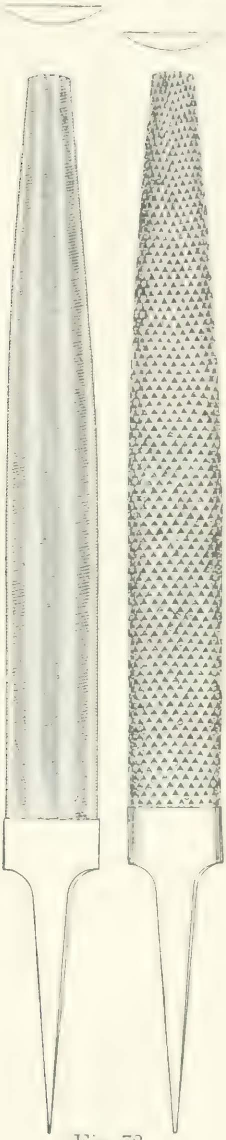


Fig. 78.

RULES.

For all ordinary measurements, a 2-foot, folding **standard rule,** Fig. 81, will be sufficient, but this rule must not be used for laying out or for working patterns, or any part of a pattern or core box, to the required dimensions. For all such purposes a **shrinkage rule** must be used. The reasons are that when a mould made from the wooden pattern in the sand is filled with molten metal, its temperature is very high, and as it cools and solidifies it contracts. Accordingly, to compensate for this, the pattern maker must add to the size of the pattern. In order that this may be done, and exact relations nevertheless be maintained for all dimensions, a shrinkage rule is used. This rule is marked off exactly like an ordinary rule; but if the two are compared, the shrinkage rule will be found to be about $\frac{1}{8}$ inch longer than the other for each foot of length.

The contraction or shrinkage of different metals in the moulds varies greatly, that for cast iron being, as above stated, $\frac{1}{8}$ inch to each foot. For brass, however, the shrinkage is $\frac{3}{16}$ inch to the foot; and for many of the softer metals it is as great as ¼ inch per foot. Shrinkage rules, Fig. 82, are usually made of a single piece of boxwood or beech, those for cast iron being 24¼ inches long, for brass 24⅜ inches long, and for other soft metals 24½ inches in length. They can also be bought made of tempered steel 12⅛ inches, 12$\frac{3}{16}$ inches, and 12¼ inches in length. In making use of the shrinkage rule, the workman will proceed just as though

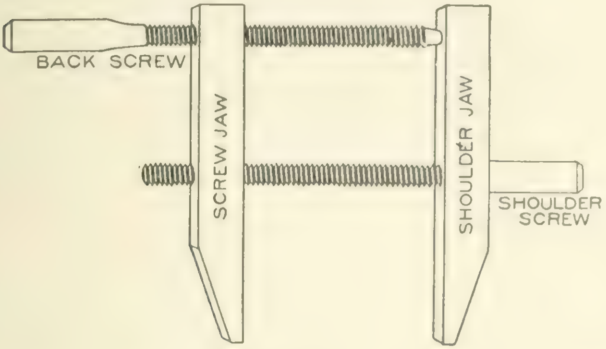


Fig. 79.

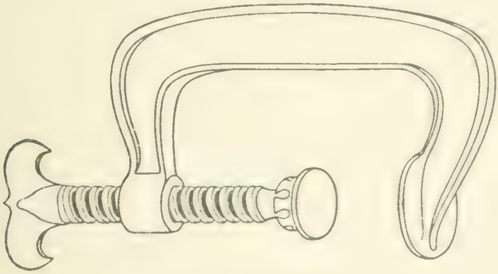


Fig. 80.

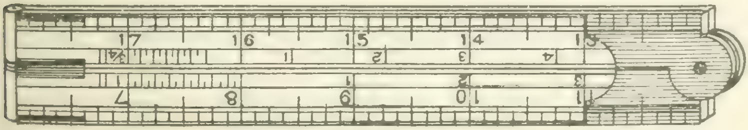


Fig. 81.

he were using a standard rule; and when the pattern is completed it will be found to be larger in all its dimensions, just in proportion

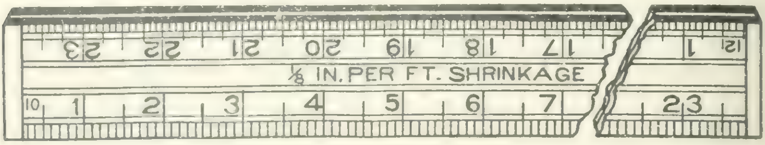


Fig. 82.

as the extra length of the shrinkage rule makes it greater than the standard rule

OIL STONES.

As before stated, new planes, chisels, and other edged tools, if of the best quality, are always sold ground and sharpened, ready for use. When used, however, they soon become dulled, and must then be resharpened, and be so kept as to have a smooth, keen cutting edge, in order to do good work and to work rapidly. The method employed for doing this is the same for all edged tools, whether ground and sharpened on one side or on both sides.

Oil stones are used for plane-irons, chisels, and all flat and straight-edged tools; and **oil slips**, having rounded edges, for gouges, and for all tools having curved edges. They are made of different sizes, and may be found of many and widely different qualities. The best known and most widely used oil stones in this country, and perhaps in the world, are the "Washita," of which the "Lily White Washita" brand, being carefully selected, are the most even in grade and quality, and are the best-adapted natural stone for woodworkers' tools.

The Arkansas oil stones are claimed to be the hardest and finest oil stones in the world. They are composed of nearly pure silica in the form of minute crystals interpenetrating one another, and differ from the Washita only in the minuteness of the crystals and in their more compact arrangement. They are consequently very much harder and cut hardened steel more slowly than coarser grades of stone, but impart a finer and smoother edge to the tool. They are used by wood-carvers, engravers, watchmakers, and others using tools that require a very fine edge or point. They are expensive, and should be used carefully with equal parts of sperm oil and glycerine.

For wood turners' and pattern makers' tools, the sharpening qualities of the "Washita" are unsurpassed; but the quality differs greatly in stones sold under this name, some being uneven in hardness, and some soft and worthless. No trouble will be found, however, if some good selected brand such as the one mentioned above is chosen. A good size for an oil stone is 6 inches to 8 inches in length, and from $1\frac{5}{8}$ inches to 2 inches in width. The thickness does not matter, but the stones usually vary from $\frac{3}{4}$ inch to $1\frac{1}{4}$ inches in thickness.

The oil slip should be about $4\frac{1}{2}$ inches in length, and from $1\frac{3}{4}$ inches to 2 inches in width, tapering from $\frac{5}{8}$ inch on one edge to $\frac{3}{16}$ inch on the other, both edges being rounded as shown in Fig. 83.

In using the oil stone, care should be taken to *hold the bevel of the tool flat, or nearly flat, on the stone*, so that the cutting edge may be kept thin and in easy working condition. The stone is held stationary on the work-bench, and the tool is moved forward and backward over its face. In the use of the oil slip, on the other hand, the tool is held stationary, with the cutting edge or end up, and the slip is rubbed over the beveled surface with a circular motion or stroke, until a keen, sharp edge has again been imparted to it. An abundance of oil should always be used in order that a finer and smoother edge may be given to the tool, and the pores of the stone be kept clean and free from glazing.

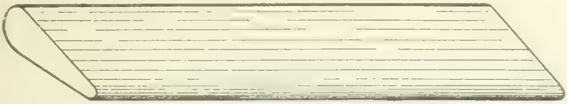


Fig. 83.

In the last few years an entirely new variety of oil stone and oil slip has been placed on the market. It is called the **India oil stone,** and is made from corundum, the hardest of all mineral substances except the diamond. These stones have wonderful cutting qualities, and differ greatly from other oil stones in that they cut steel much faster, impart better edges, and do not glaze. They are also of uniform texture throughout. India oil stones are furnished in three grades—coarse, medium, and fine—and in all required shapes, a few of which are shown in Fig. 84. Only the "fine" stones are adapted for woodworking tools and for those classes of tools requiring a fine cutting edge.

GRINDSTONES.

Second in importance to a good oil stone is the grindstone, power-driven if possible. It should not be too close-grained. A rapid-cutting stone, even if moderately coarse, is greatly to be preferred, as all ground edges must be finished on the oil stone however finely they may have been ground on the grindstone.

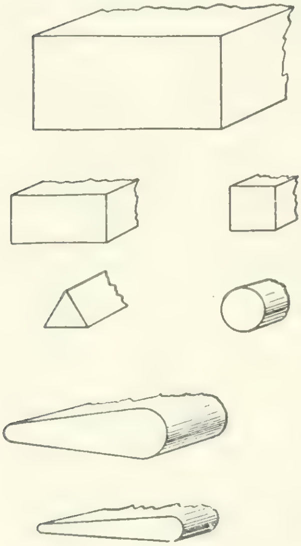


Fig 84.

A stone about 36 inches in diameter when new, is a good size; and can be bought with a suitable cast-iron trough underneath, and also with an arrangement for supplying the water necessary to keep the stone wet.

In all stones there will be found great differences of hardness in different parts. Stones soon lose their cylindrical shape and must be turned true. A piece of gas-pipe or an old file will be found excellent tools for this purpose, but they must be used without water.

In using the grindstone for plane-irons, chisels, and other tools that must be ground with a long bevel, or to a thin edge, it is better to stand so that the stone runs toward the cutting edge of the tool, as shown in Fig. 85. This position grinds the tool much faster, and less of a feather will be turned up on the final edge.

Scraping tools, however, and indeed all tools having a very short bevel, or whose edges are ground to a very obtuse angle, may be held so that the stone will revolve away from the cutting edge of the tool, this position being less liable to cut hollows in the face of the stone. This method of grinding, however, is too slow for tools having a long bevel, and which for that reason require more grinding.

When to use the grindstone is a question that often occurs to the beginner, who sometimes confuses the use of the grindstone with that of the oil stone. The grindstone is not in any sense an instrument for *sharpening* woodworkers' tools. When a chisel or a plane-iron has been sharpened on the oil stone for several successive times, the bevel is gradually worn shorter, and its shape changed from that shown at *a*, Fig. 86, to a shape similar to that

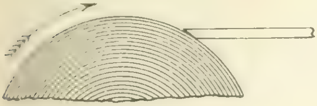


Fig. 85.

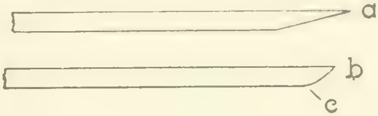


Fig. 86.

shown at *b*. When the length of the bevel is thus reduced, the angle of the cutting edge is too obtuse to do good work, or to work easily. The metal at *c* must then be ground off on the grindstone, and the bevel of the tool restored to its former correct shape as shown at *a*, after which the cutting edge must be sharpened and finished on the oil stone.

LATHES.

Of all power-driven machines, the most indispensable to the pattern maker is the **wood turning lathe.** In a small shop where small patterns only are made, a 14-inch or a 16-inch speed lathe, such as is shown in Fig. 87, may prove sufficient for all purposes; but if only one lathe can be afforded, it should be a regular patternmaker's lathe, similar to that illustrated in Fig. 88.

The latter differs from the speed lathe in that the head-stock spindle extends through the left-hand bearing, and is fitted to receive face-plates and chucks, the same as on the inside end.

The arrangement of the countershaft is also such as to give a much wider range of speed to the lathe head, so that pieces of very large diameter may be turned at a speed proportioned to their sizes. These lathes are also fitted with a hand-feed slide rest —either compound, as shown in the illustration, or a plain sliding tool-holder moved by a rack and pinion, as may be desired. The tail stock is so arranged as to be adjustable for turning long cylinders, either tapering or straight, as may be required. When not in use the slide rest may be removed from the lathe, and the ordinary tool rest and rest socket substituted in its place for hand turning.

The speed at which a lathe should be run is always indicated by the manufacturer, the countershaft usually running at a speed of 500 to 550 revolutions per minute.

A variety of **chucks** and **face-plates,** used for holding the work, are always furnished with a lathe. Some of these are shown in the engraving, the screw chuck being shown at *a*, Fig. 88; and two of the iron face-plates are shown, one on each end of the spindle.

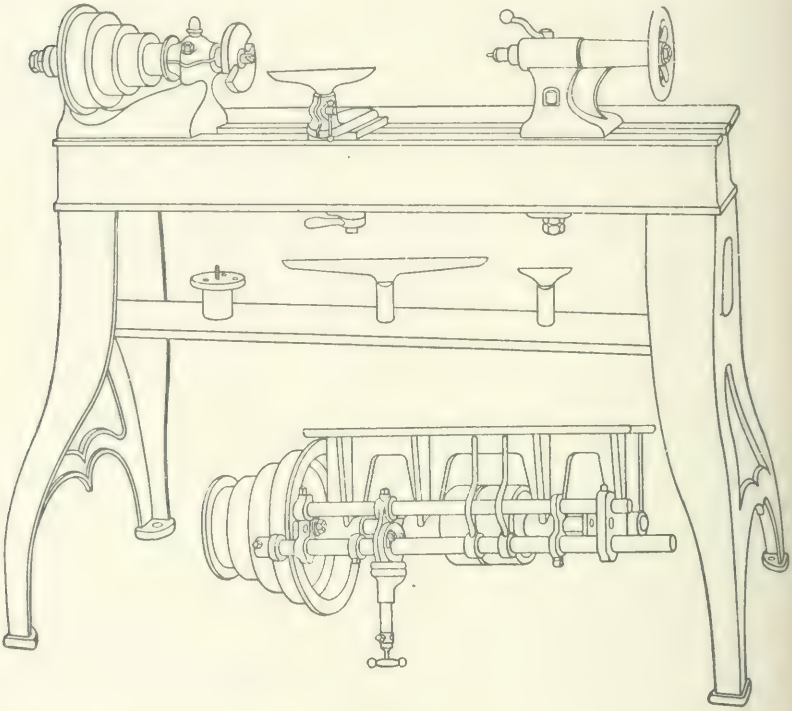


Fig. 87.

But in addition to these face-plates, which really form the base only for chucking the pattern, **wooden chucks** must be used intermediate between the iron face-plate and the pattern. These wooden face-plates are constructed in a variety of ways by different pattern makers; but for small patterns it is necessary to use only a plain board $\frac{7}{8}$ inch to $1\frac{1}{4}$ inches in thickness and of a slightly greater diameter than the required pattern. This board is screwed fast to the iron face-plate as shown in Fig. 89, to which, after being placed in the lathe and turned true, the pattern is attached, as will be fully illustrated and described farther on. For patterns of a medium size, say 20 inches to 30 inches in diameter, the board should be stiffened by means of a wide wooden bar firmly screwed across the back, as in Fig. 90.

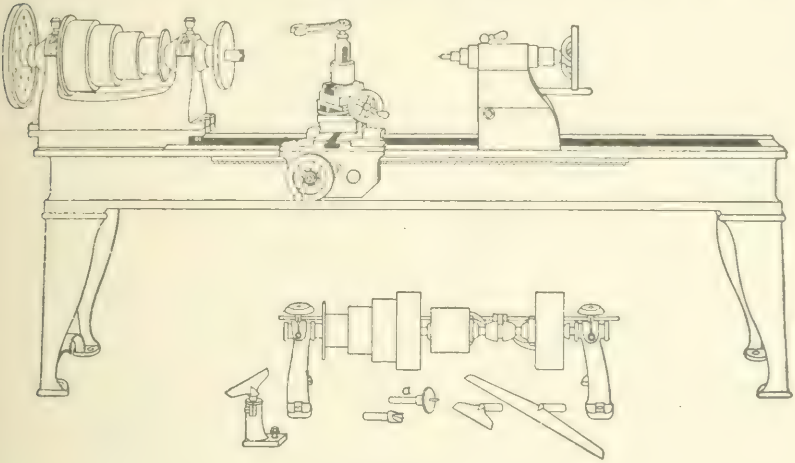


Fig. 88.

When chucks are needed for very large or heavy work, the chuck, in order to prevent vibration, must be strong in proportion. It is best made as illustrated in Fig. 91, in which the front of the chuck, as shown at *a*, will be least affected by the moisture in the air if left unglued, or at best only tongued and grooved, being held together by the cross-bars only, as shown at *b*, to which it is firmly screwed, without glue. This chuck is simple and cheap, and will be found in practice much stronger and more rigid than one built up out of sectors or in a more elaborate way.

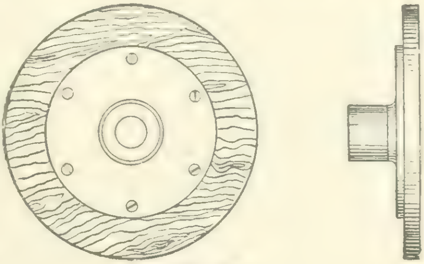


Fig. 89.

LATHE TOOLS.

Of lathe hand tools the first to be considered, as also the first to be used, is the **gouge.** It is used for reducing the stock to be turned, from a rough or rectangular shape to a cylindrical form, preparatory to smoothing and finishing. It is ground and beveled on the back or convex side, and the shape of the cutting edge should be of the same curvature as the inside, or upper side, of the tool. Gouges are made in all sizes, one of which is illustrated in Fig. 92; but for the pattern maker's use four gouges, ranging from $\frac{1}{4}$ inch to $1\frac{1}{4}$ inches, will be found sufficient for all purposes.

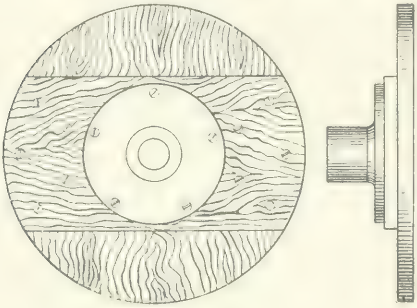
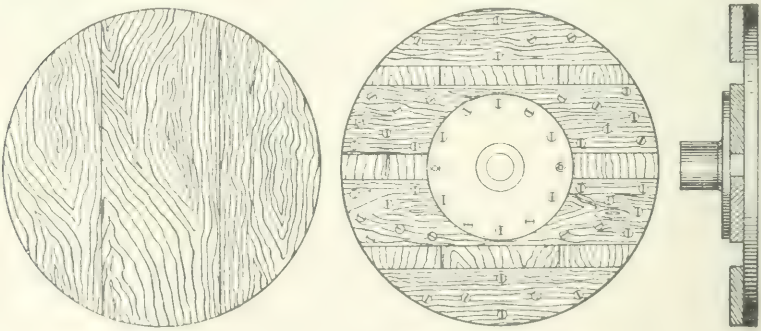


Fig. 90.

Before using the gouge, and indeed any lathe-cutting tool, the workman should take care to see that the tool rest has been elevated above the center line of the lathe centers, from $\frac{1}{4}$ inch for small work to 1 inch or more for large work. The position of the gouge, when in use, is horizontal and at about a right angle to the tool rest. It should not, however, be laid on the rest so as to use only the extreme point of the tool, but should be tilted over, first to one side and then to the other, so as to bring all parts of the cutting edge, successively, in contact with the wood that is being turned.



a Fig. 91. *b*

The gouge may be used by the beginner without hesitation, as in no position, whether tilted or on its back, will it catch or rip into the wood. The tool should be held firmly by the extreme end of the handle, in the right hand, while the left hand rests against the tool rest, the blade of the tool being grasped lightly with the fingers, and passing through and under the left hand while resting on the tool rest.

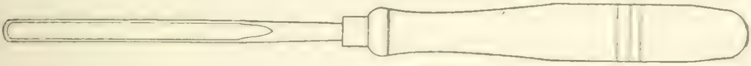


Fig. 92.

The turning gouge, being curved, can be used only as a roughing-down tool or for turning out hollows, and cannot be used for finishing. It will not make a straight, true, or smooth surface. For this purpose, in common and ornamental turning, the **skew chisel,** one size of which is shown in Fig. 93, is used. This form of chisel is made in all sizes from ⅛ inch to 2½ inches in width, but, unlike the gouge, requires considerable practice and skill for its successful use.

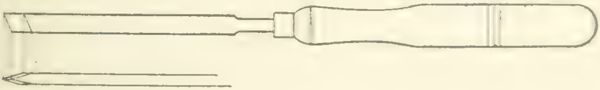


Fig. 93.

The skew chisel is held slightly tilted so that while the short edge of the blade touches the tool rest, the long edge will be slightly above the rest, so that the long corner of the skew point extends *up* and well *over* the cylinder which is being smoothed, thus preventing the long skew point from catching and tearing into the work. All the cutting must be done with the short part of the skew edge, say one-half inch only of the cutting edge, the tool resting not only on the tool rest, but resting also firmly on the cylinder that is being turned, just as a plane rests on a board while cutting and removing the shavings from its surface. The right position for this tool is hard to obtain at first, and can be acquired only by patient and continued practice. In no case, however, should the skew chisel be held *flat* on the tool rest, or used as a scraper, this not being allowable or good practice either in common or in ornamental turning. One skew chisel each of the ¼-inch, ½-inch, 1-inch, and 1½-inch sizes will be found sufficient for all ordinary work.

While the skew chisel works with great rapidity and does smooth and very satisfactory work in all kinds of ornamental turning, the dimensions obtained with this tool are not so accurate for pattern work as those obtained by the regular pattern maker's **scraping tools.** These tools, whatever may be the shape of the points or cutting edges, are all flat like the skew chisel, and are ground or beveled on one side only. Indeed there is no better wide scraping tool for large surfaces than a common firmer chisel after it has been worn short so as to be free from vibration.

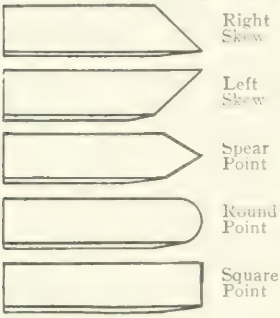


Fig. 94.

Scraping tools are made in many forms and shapes, and are ground by the workman to suit the requirements of his work. A few of the many shapes in common use are illustrated in Fig. 94.

These tools should be ground with a very short bevel, and must be sharpened much oftener than a cutting tool. The revolving wood, passing at right angles to the sharp edge wears it away more quickly than it can a cutting tool, for the latter is also worn away on the slanting side of the bevel.

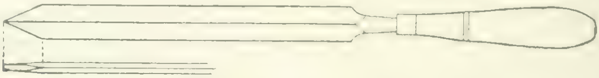


Fig. 95.

A very necessary tool for all kinds of wood turning is the **parting** or **cutting-off tool,** shown in Fig. 95. This is used as a scraping tool for cutting recesses in the work and for cutting off finished work from the face-plate, and will also be found useful for many other purposes.

SAWING MACHINES.

As a time-saving and labor-saving machine a good **circular saw bench** is necessary in every well-equipped pattern shop.

The saw bench of which two views are shown in Fig. 96, is unsurpassed in capacity and in the variety of work for which it may be used. It is provided with two saw arbors, one of them carrying a rip and the other a crosscut saw, either of which can

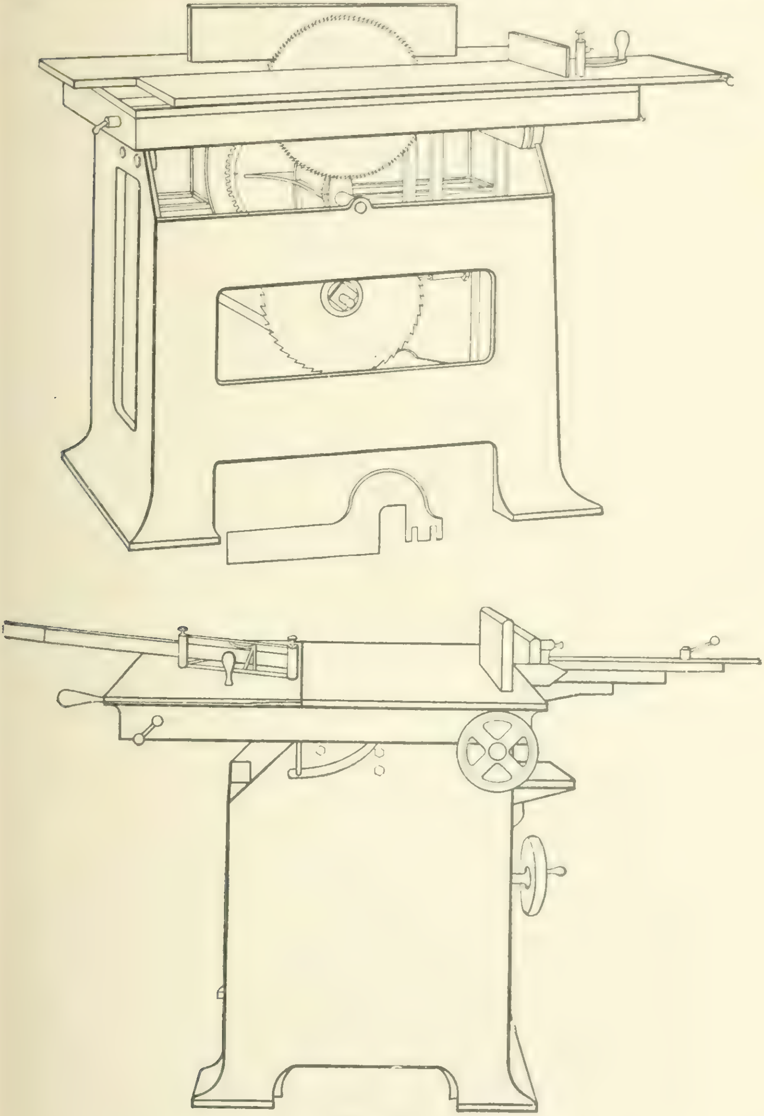


Fig. 96.

easily and quickly be raised to a cutting position. The front half of the table is made to slide, while the whole table can be tilted to an angle of 45°, and will remain in any position desired without clamping. As shown, it is provided with adjustable gages for crosscutting or mitering, and with an adjustable fence for ripping, all of which are removable at will, leaving the whole upper surface of the table clear. Fig. 97 gives a view of the table from above. As in the case of the turning lathe, the intended speed of the saw countershaft is indicated by the manufacturer.

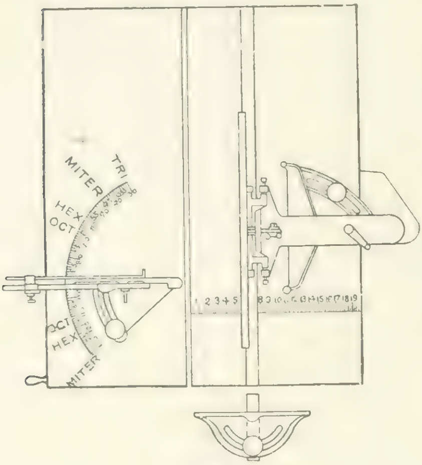


Fig. 97.

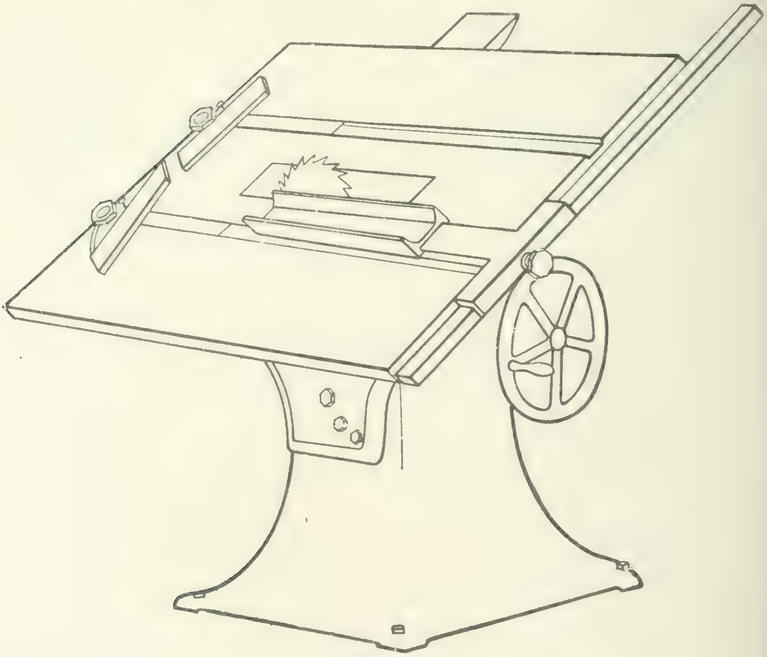
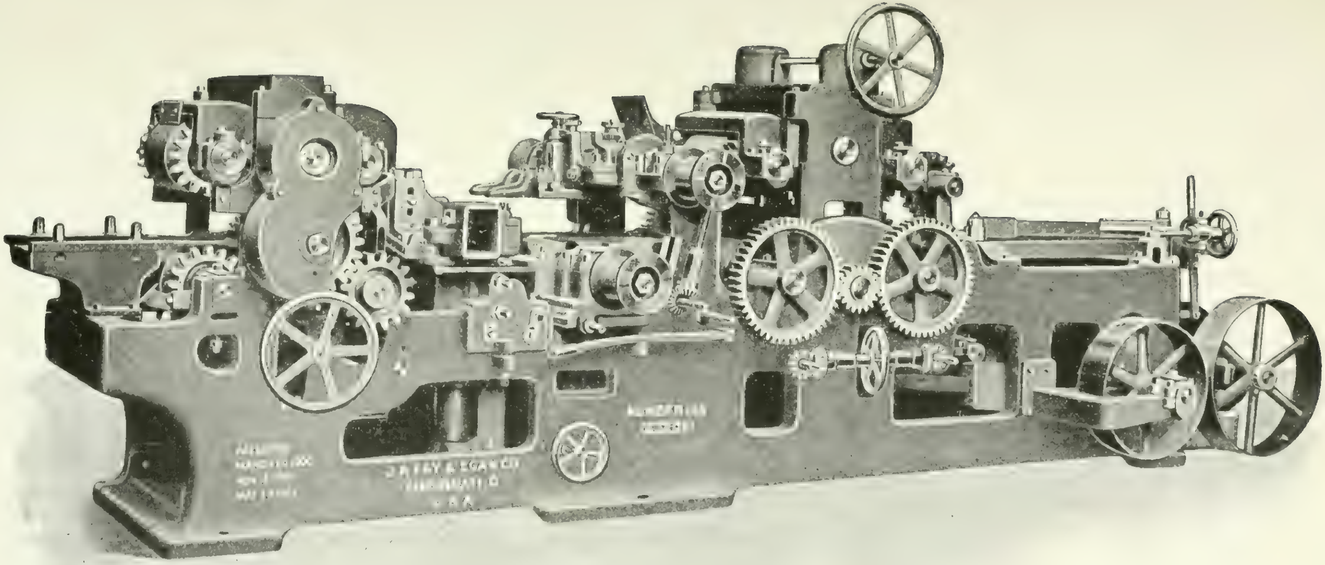


Fig. 98.



FLOORING MACHINE.
J. A. Fay and Egan Co.

The single-arbor circular saw bench shown in Fig. 98 is a less expensive machine than that just described; but the time lost in having continually to change the saw on the single arbor from rip to crosscut and back again for pattern work, is a very annoying as well as expensive inconvenience.

BAND AND SCROLL SAWS.

A good **band saw**, such as the one illustrated in Fig. 99, is indispensable for cutting the curves and irregular shapes that form a part of so many patterns.. The best machines of this description have a tilting table which can be set and clamped at any angle, enabling the workman to give the required level or draft to his work.

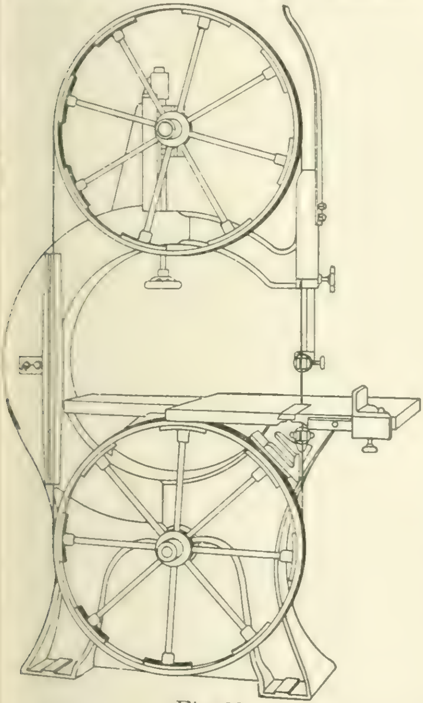


Fig. 99.

With a sharp and well kept saw, there is no more rapid or correct method of cutting out and making circular core boxes of all sizes whose length is within the capacity of the machine. The block from which the core box is to be made must be cut perfectly square on the end that is to rest on the saw table; and, if this end of the block is not large enough to give sufficient base to hold it in an upright position, the block can be supported against the blade of a try-square, or, better still, against a wooden bracket made for the purpose.

The **scroll saw**, illustrated in Fig. 100, is necessary for cutting inside curves and openings in which a band saw could not be used. Like the band saw it should have a tilting table. Where both saws cannot be afforded, the scroll saw will take the place of both.

While not working so rapidly as the continuously cutting blade of the band saw, it is, when kept sharp and in good running condition, a great time- and labor-saving machine.

PLANING MACHINES.

Because of the fact that pattern lumber can be bought already dressed to any required thickness, a planing machine is not found in every pattern shop. The ordinary surface planer, however, will not take the twist, or wind (*i* as in *find*), and the curves out of the surface of the lumber—a matter of very great importance in pattern work, and one which requires a great deal of time if the planing is done by hand.

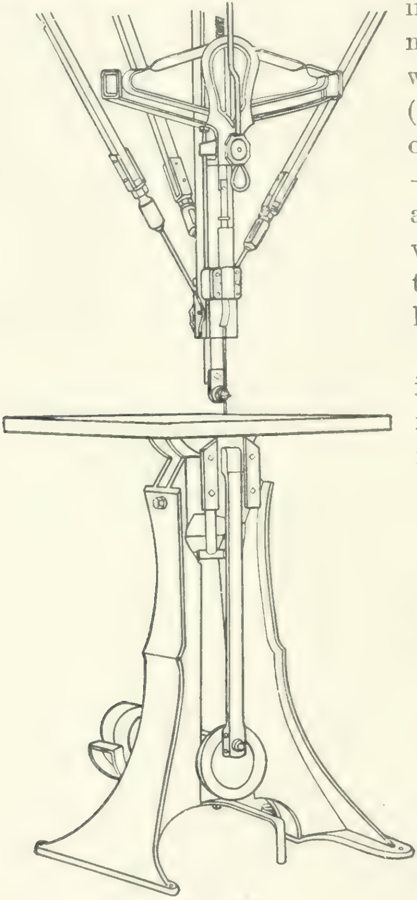


Fig. 100.

The **hand planer and jointer**, illustrated in Fig. 101, is almost indispensable, not only for facing the sides of boards perfectly true, straight, and free from wind, but also for jointing the edges, and for making perfectly-fitting glue joints in a manne superior to any hand work These machines can be bough in widths of from twelve to thirt inches. A machine sixtee inches wide is a very desirabl size for pattern work.

It will readily be seen tha the running of a board over th hand planer, while facing th surface straight and true, will not reduce the piece to a unifor thickness. To avoid the necessity for much hand work in accomplishing this result, first face the piece on the hand planer so to make one true side, and then run it through a surface plan similar to the one illustrated in Fig. 102. If they can be afforded, both of these machines (especially the hand planer) will return large profits on the money invested in them, because of the time

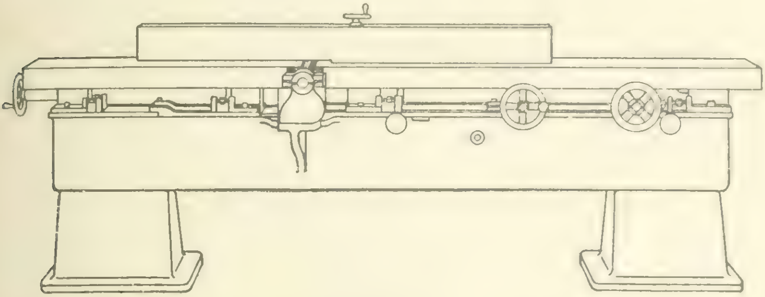


Fig. 101.

and labor saved and the superior quality of the work done.

Among the many labor-saving tools of late years, there is perhaps none more popular and none more indispensable in a

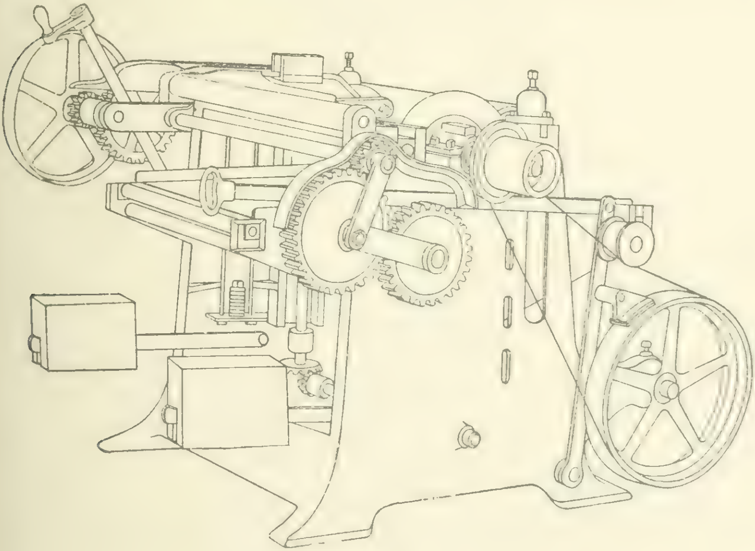


Fig. 102.

pattern shop than the **universal wood trimmer.** It will cut any end or angle within the capacity of the machine; and an end which would take from ten to fifteen minutes to square and true up correctly by hand with square and plane or chisel, can be finished in as many seconds with this tool. It is made in many sizes, from the small bench trimmer, two views of which are shown in Fig. 103, to the large machine illustrated in Fig. 104. The former will cut 6 inches wide and 3 inches high. The larger machine will cut 20½ inches wide and to a height of 7½ inches.

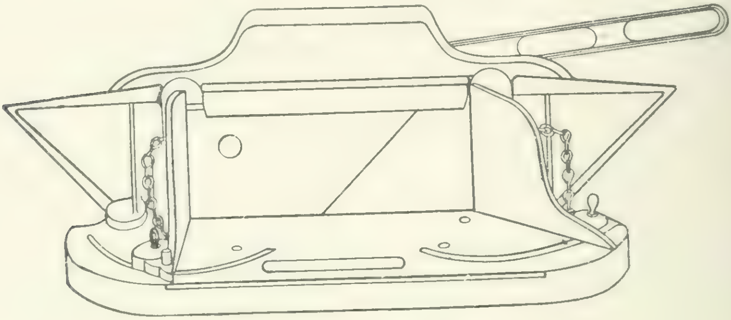


Fig. 103—Front View.

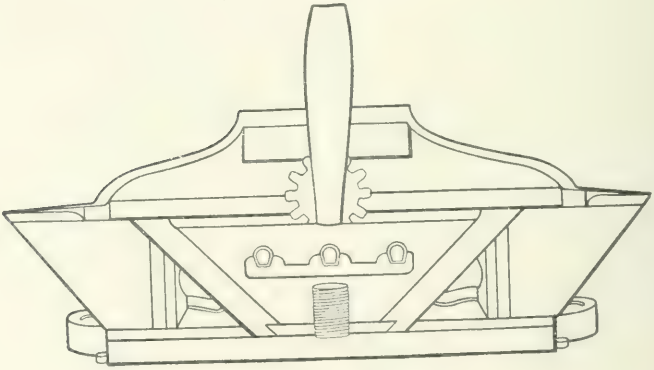


Fig. 103—Rear View.

The small No. 0 machine, shown in Fig. 103, is so comparatively inexpensive, and the time it will save so great, to say nothing of the quality of the work produced, that it should be on the bench of every pattern maker. These machines will cut the acute angles between 45° and 90°, and the obtuse angles between 90° and 135°.

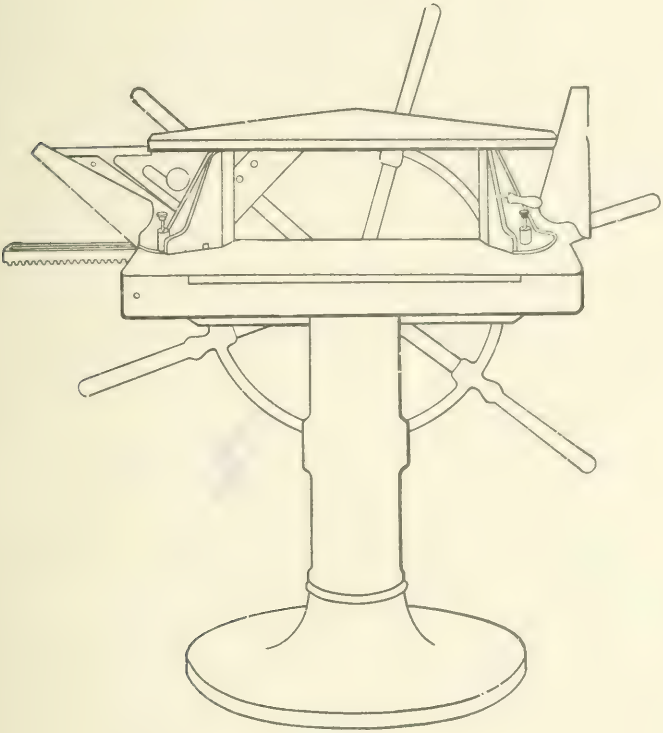


Fig. 104.

METHODS OF MOULDING.

As has already been said, it is necessary that the patternmaker should have some knowledge of moulding in order that he may construct his patterns so that they can easily be removed from the sand. A brief description of the general method employed will suffice.

Ordinarily, a casting is made in a **flask** consisting of two parts, each containing its complement of sand. The upper part is called the **cope,** and the lower part the **nowell** or **drag.** The pattern is sometimes made in two pieces that *part* along the line separating the cope and the drag. Thus in Fig. 105 the pattern separates with the flask, on the line A B; and when so separated, the cope is turned upside down and the portion of the pattern C is lifted out. The part D is lifted out of the drag in the same way.

In the case of moulding a hollow object, the internal cavity in the casting is formed by means of a dry sand **core**, which rests in impressions made in the sand by **core prints** attached to, and forming a part of, the pattern. To illustrate this, let it be required to cast the hollow cylinder shown in Fig. 106. The wooden pattern necessary to produce this hollow cylinder is shown in Fig. 107, which, as will be seen, represents the cylinder only externally by the part A.

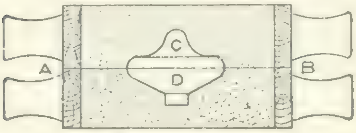


Fig. 105.

The core prints, one on each end of A, are represented by *x* and *y*. These projections form part of the pattern, and make their impressions in the sand with the part A, which alone represents the required cylinder. The **core box**, in which the dry sand core is formed, is shown in Fig. 108. The length of the inside of the box will be the extreme length of the pattern including *x* and *y*, and the inside width will be the exact diameter of the core prints. In this case, the core being a cylinder, only a half core box (Fig. 108) is used. In it are made two semi-cylindrical cores, which, after being dried, are cemented together, thus forming the complete cylindrical core required.

Fig. 106.

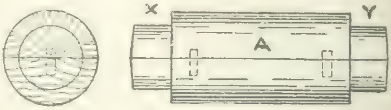


Fig. 107.

To mould this halved or *partea* pattern as it is called, the upper half of the pattern is laid on the moulding board, and the *drag* is turned over it with the bottom side of the drag up and the parting side on the moulding board, as shown in Fig. 109. After being "rammed up," the drag and moulding board are turned over and the board removed, when the parting of the pattern will be exposed, the half pattern being imbedded in the sand.

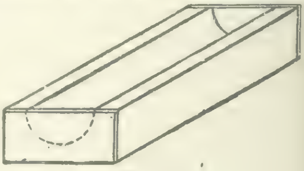


Fig. 108.

The second half of the pattern is now placed in position on the first, and dry **parting sand** is spread over the surface of the wet or "green" sand; the cope is put in position on the drag, as shown in Fig. 110, and rammed up. Upon the cope and the drag being separated, the sand will separate on the line to which the parting sand has been applied, which, as will be seen, is the line of parting of the cope and the drag, one half of the pattern remaining in each.

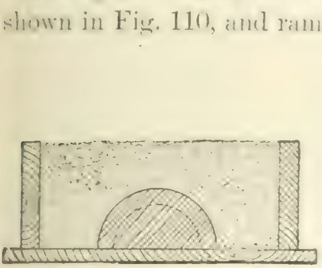


Fig. 109.

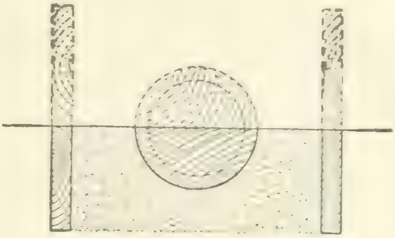


Fig. 110.

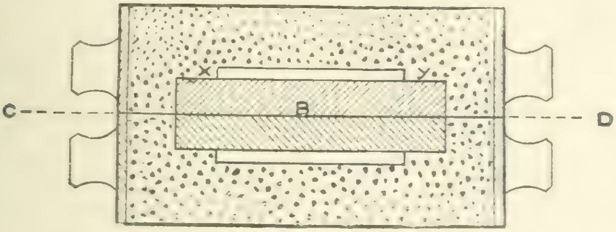


Fig. 111.

After the pattern has been removed (one half from the cope, and the other half from the drag), the completed dry sand core is placed in the moulds made by the core prints *x* and *y*. This core B is shown in position in Fig. 111 and entirely fills the parts of the mould made by *x* and *y*, leaving between itself and the surface of the mould made by A, room for the metal to be poured which is to form the required cylinder.

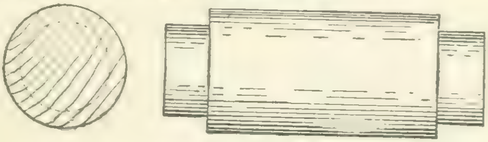


Fig. 112.

In moulding the above cylinder it is not necessary that the pattern should be parted (made in two halves) as shown in Fig.

107. Patterns for small work, and even for large castings, are often made in one piece, as shown in Fig. 112. To mould this solid pattern it is placed on the moulding board with sufficient sand to keep it from rolling, and the drag is inverted over it as before. When the drag has been rammed up, it is turned over, and will then present the appearance shown in Fig. 113, the entire pattern being embedded in the sand. The sand is now cut away and removed, as shown in Fig. 114, down to the center line of the pattern. The cut sand is smoothed; and, after dry parting sand has been applied to the surface of the wet sand, the cope is placed in position and rammed up as usual.

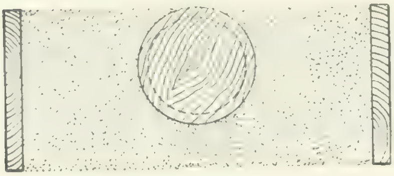


Fig. 113.

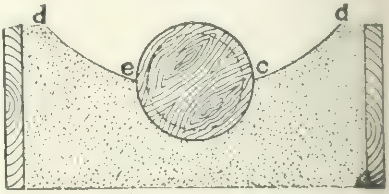


Fig. 114.

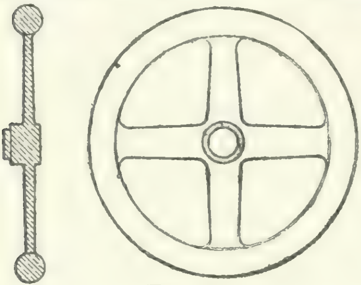


Fig. 115.

Upon the cope being removed, the sand will part along the lines *d e* and *c d*, leaving one-half of the entire pattern exposed. The pattern can now be lifted out, the core placed in position, and the cope returned to its place on the drag, when it is ready for the pouring, as in Fig. 111.

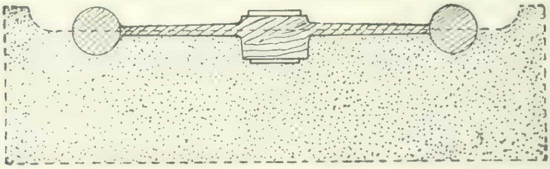


Fig. 116.

Another example of a one-piece pattern is the small brass hand wheel shown in Fig. 115. The pattern for this wheel is placed on the moulding board, and the drag inverted over it and rammed up. After the drag has been turned over, the sand is cut away and removed, not only down to the center of the rim, but also to the center line of the four arms, as shown by the dotted lines in Fig. 116.

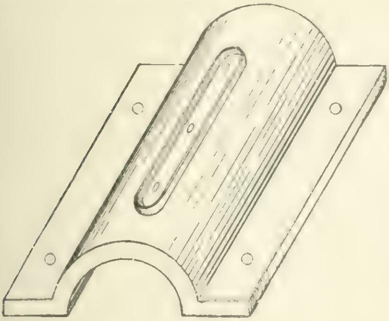


Fig. 117.

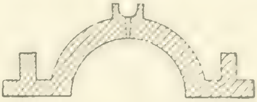


Fig. 118.

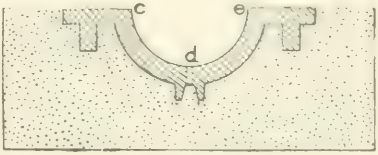


Fig. 119.

All cut surfaces of the sand are smoothed, parting sand is sprinkled over the parting thus made, and the cope is placed in position and rammed up. When the cope is lifted off, the sand will part half way down on the arms and rim, allowing the pattern to be taken out with ease.

Still another example in which a single-piece pattern can be used, is shown in the journal-box cap illustrated in Fig. 117. A cross-section of the pattern through two of the bolt-hole core prints is shown in Fig. 118. The pattern is placed on the moulding board in the inverted drag and is rammed up as usual. When the drag is turned over, the position of the pattern in the sand is as shown in cross-section in Fig. 119. The sand that may have entered the curve *c d e* is lifted out, and the necessary "draft" is given to the sand at the two ends of the opening *c d e*, as shown at *a*, Fig. 120. The cope is next placed in position, and when this has been rammed up and lifted off, the sand lying in the curve *c d e*

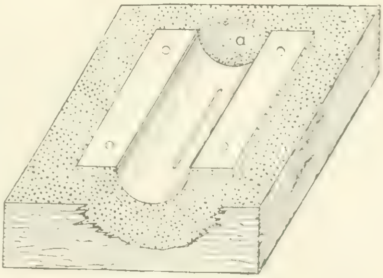


Fig. 120.

will be lifted with it. The pattern is now removed; the bolt-hole cores are placed in position; and the cope is returned to its place on the drag.

In this case the core prints should be in length at least twice the thickness of the metal through which the hole is to be cast, and the length of the cores will be equal to the thickness of the metal plus the length of the prints.

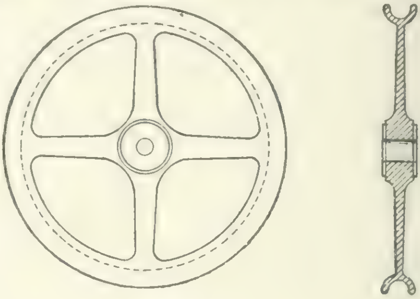


Fig. 121.

In the small sheave pully, Fig. 121, we have an example of a casting the construction of the pattern for which, so as to make it easily removable from the sand, may give some trouble to the beginner. The pattern is shown in cross-section in Fig. 122, and is moulded in a two-part flask. At first it would seem impossible to place the pattern in the sand so that either half could be removed when the cope and drag are separated on the parting line of the pattern. This is readily accomplished, however, as follows:

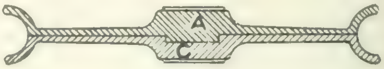


Fig. 122.

The half pattern C is placed in the inverted drag, with the parting downward on the moulding board, and is rammed up in the usual way. After the drag is turned over, the sand is cut away and removed to the center of the rim edge, as shown in Fig. 123. The cut is carefully smoothed, and parting sand applied to the cut surface. The part A of the pattern is placed in position on C, and is rammed up carefully, the sand being then cut away to the center of the rim edge of A. Parting sand is applied to the new surface, after which the cope is placed in position and rammed up.

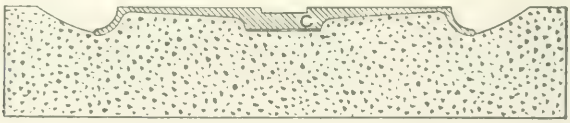


Fig. 123.

When the cope and drag have been separated, the upper half A of the pattern is taken out, and the cope is returned to its place on the drag. The whole flask is now turned over, and the drag lifted off the cope, when the ring of green sand Z, Fig. 124, will rest on the cope sand and the part C of the pattern is taken out. We thus have two partings of the sand mould, but only one parting of the flask.

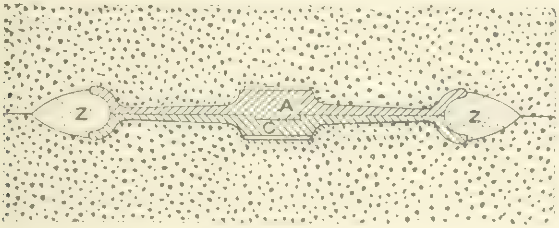


Fig. 124.

Many other examples might be given, as the case of the common two-flange pulley, which, when small, is often moulded in this way.

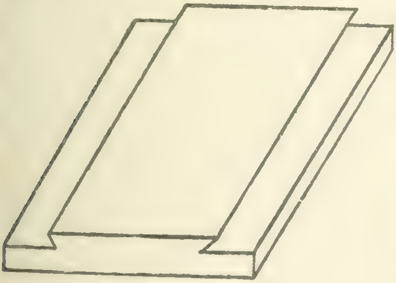


Fig. 125.

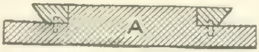


Fig. 126.

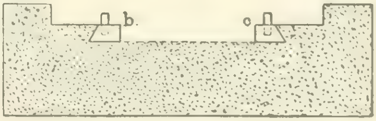


Fig. 127.

It is frequently the case that parts of the pattern will overhang so that the pattern cannot be removed from the sand in any direction, even if parted. In such cases the overhanging parts are fastened loosely to the main part of the pattern by wires or wooden pins. An example of such a casting is shown in the slide, Fig. 125. A cross-section of the pattern for this slide is shown in Fig. 126, in which the two overhanging parts are held in position by the use of pins. After being rammed up, the part A is removed, leaving the parts *b* and *c* still in their positions in the sand, as in Fig. 127. These may now be carefully moved toward the center of the opening and lifted out.

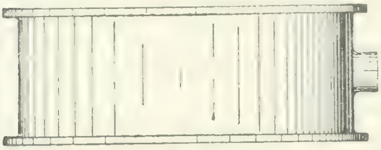


Fig. 128.

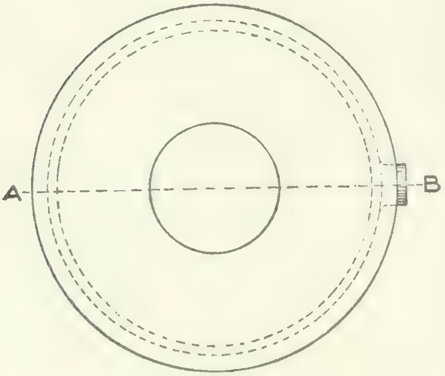


Fig. 129.

In some cases there is not sufficient room, when the main part of the pattern has been taken from the mould, to remove the projecting pieces. In such cases, the overhanging pieces or projections must be made by using dry sand cores. To illustrate this, we shall consider the pattern for the small cast-iron turbine case illustrated in Figs. 128 and 129. A section view of the casting through A B (Fig. 129) is given in Fig. 130.

The pattern is parted on the line C D and will form its own core. The boss *a*, however, will prevent the main part of the pattern from being removed from the sand, and if *a* were made loose it could not be taken out through the narrow space made by the thin side of the pattern. To overcome this difficulty a core print is fitted on the side, extending from the parting line C D to the bottom edge of the pattern, as illustrated in Figs. 131 and 132; and in the impression made by this core print a dry sand core, formed in the core box shown in Fig. 133, is placed. It will readily be seen that this core will, in connection with the pattern, form a mould which will give the casting required.

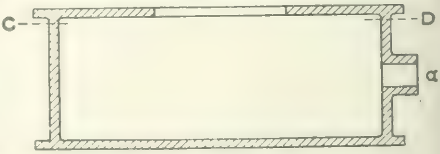


Fig. 130.

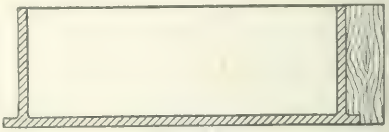


Fig. 131.

Examples in "Methods of Moulding" could be multiplied indefinitely, but the foregoing, we think, will give such suggestions as will enable the beginner in pattern making to construct all

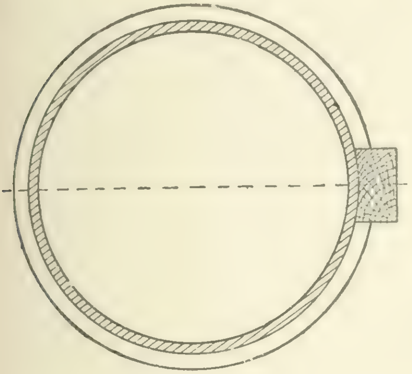


Fig. 132.

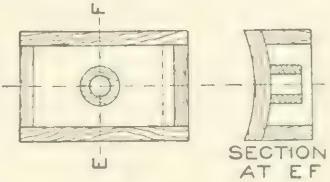


Fig. 133.

ordinary patterns so that they can easily be removed from the sand without injury to the mould.

PATTERNS FROM DRAWINGS.

As already explained, the pattern maker must understand working drawings in order to construct patterns from them directly. These drawings are usually made to a scale much less than the actual size of the required work, and always represent the completed or *finished* machine or one of its parts.

Drawings are made for the machine shop to guide the machinist in cutting, turning, planing, and fitting the parts given, so as to produce in the castings the shapes, sizes, and general requirements of the articles to be constructed. Hence there is less liability for mistakes after the castings reach the machinist, as he has before him not only the drawing with its accurate dimensions to work from, but also the castings for the machine or its parts, from all of which the construction and uses of these several parts can easily be understood.

On the other hand, the pattern maker, with the aid of the same drawing, must *imagine* the casting before him, and must build something in wood which will produce that casting in metal. This pattern, in some cases, will be a duplicate of the required casting, but more often it has only a general resemblance to it.

with core prints attached, and is external only, with nothing to show the internal openings, chambers, and winding passages that must be provided for by "coring." The core boxes, in which the cores are to be formed, are not shown in the drawings furnished to the pattern maker, but must be provided by him in correct shapes and sizes, in addition to the pattern itself with its added core prints.

In building a pattern the workman, as before stated, must allow for **shrinkage.** He must also allow for **draft** and for **finish.**

Shrinkage. The shrinkage of cast iron when cooling in the moulds is, as has before been stated, about $\frac{1}{8}$ inch to each foot, and the manner of obtaining the exact sizes for different parts of the pattern has been explained under the head of "Rules" (page 38). For brass or bronze castings a greater allowance must be made, averaging $\frac{3}{16}$ inch to each 12 inches. Shrinkage rules for brass ($\frac{3}{16}$ inch to the foot) can be obtained, and must be used for all patterns made from brass.

Draft. After shrinkage, the second point of importance in a well-made pattern is draft. By this term is meant the bevel or taper made on all vertical parts of the pattern so that it can easily be lifted from the sand without injury to the mould. This is best illustrated as in Fig. 134, in which it will be seen that if the diameter of a pattern at *a* were to be the same as that at *b*, the latter point would drag over the whole length of the sand until it reached the former point. As the sand is held together only very lightly, this dragging would be likely to dislodge some of the particles and make it necessary to mend the mould. In order to avoid this, the diameter at *a* is made slightly greater than at *b*, so that the body of the gland is tapering, and the moment it is started out the whole surface from *a* to *b* is clear of the sand and can be removed without injury thereto. This difference in the diameters at *a* and *b* is called the *draft* of a pattern. The amount of draft depends upon the length of the part that is to be drawn out of the sand.

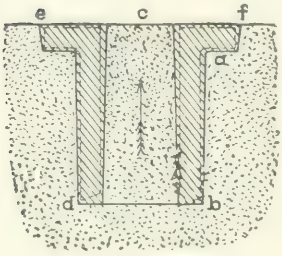


Fig. 134.

The allowance for draft varies with the pattern, and is often greater or less on different parts of the same pattern. For example, the draft on the outside of the pattern of a pulley rim 24 inches in diameter and 6 inches face, should be $\frac{1}{8}$ inch to the foot, while on the inside of the rim and on the hub of the pully it should be in the ratio of $\frac{3}{8}$ inch to the foot. The reason for this difference is that the face of the rim is often turned and finished *straight*, and for that reason the least possible amount of draft that will allow of the pattern being removed from the sand should be used; while on the inside of the rim a greater amount of draft strengthens the metal rim, which must sustain the strain and pressure of the belt. In general the draft should be from $\frac{1}{8}$ inch to $\frac{3}{8}$ inch for each 12 inches, the latter amount in all cases where the removal of the metal thus added will not greatly increase the expense of working the casting. To obtain any required amount of draft correctly, a draft template, kept with other tools and templates, will be found convenient and useful, saving much time when changing from one ratio of draft or bevel to another. It is made as follows:

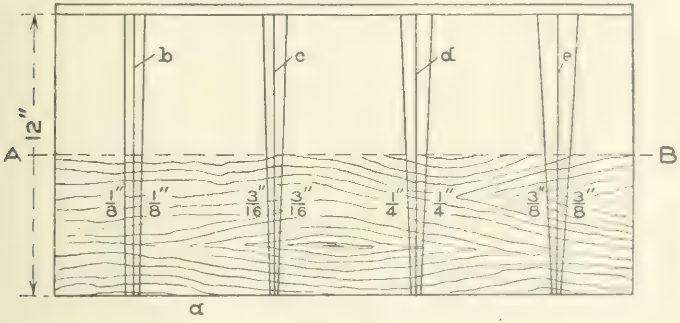


Fig. 135.

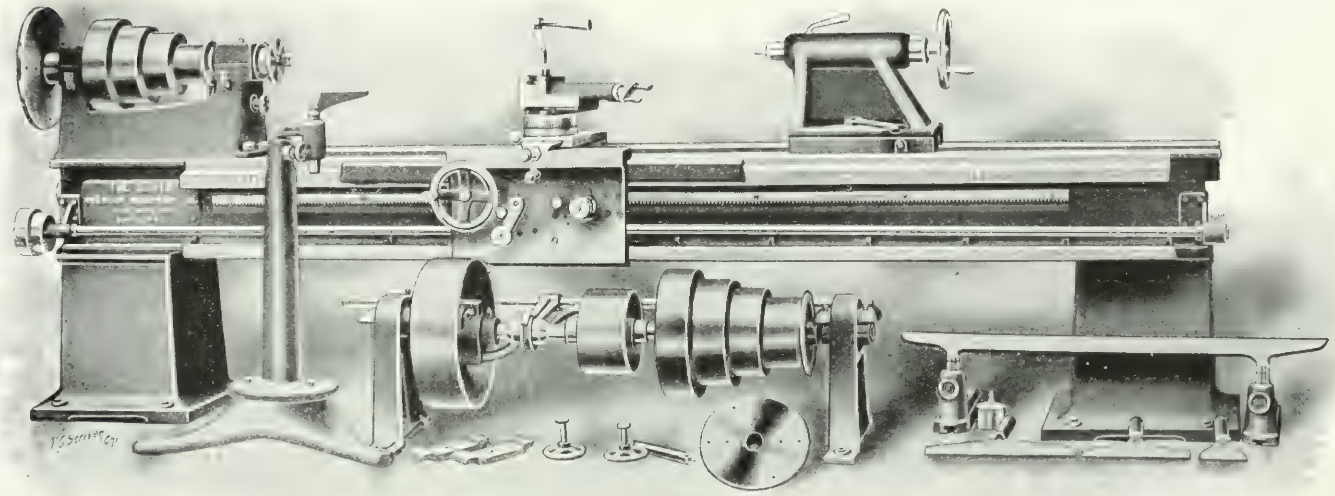
Take any straight-grained board 14 inches to 16 inches long and 12¼ inches wide, as shown in Fig. 135. Having jointed the edge *a* perfectly straight, draw the line *b* perpendicular to the edge and 12 inches long, using a square and a sharp-pointed knife (not a scratch-awl or a lead pencil). On the edge *a* carefully measure $\frac{1}{4}$ inch on each side of *b;* and at the upper extremity, with the same care, measure $\frac{3}{8}$ inch on each side of *b;* connect the last two points thus found with the first two on the edge *a*, by a sharp knife line, and the result will be a right and left slanting line, having, with reference to the perpendicular, a slant of $\frac{1}{8}$ inch to a foot. These lines should each be marked "$\frac{1}{8}$ inch," as shown in the drawing.

Now draw a second perpendicular *c*, at a distance of $1\frac{1}{2}$ inches or 2 inches from the first. On the edge of the board *a*, again carefully mark off $\frac{1}{4}$ inch on each side; at the other extreme mark off $\frac{7}{16}$ inch on each side of *c*, and again connect the latter points with the former. The result will be a taper of $\frac{3}{16}$ inch to a foot. Again repeat the process, making the taper $\frac{1}{4}$ inch, and lastly $\frac{3}{8}$ inch, to a foot. Mark the pairs of right and left-hand tapers respectively $\frac{1}{8}$ inch, $\frac{3}{16}$ inch, $\frac{1}{4}$ inch, $\frac{3}{8}$ inch, as shown. These lines having been obtained permanently, the width of the board may be cut down from $12\frac{1}{4}$ inches to 6 inches (as shown by the dotted line A B), and the board then shellaced.

To use this template, place the bevel against the edge *a* of the board, and carefully adjust the blade to the $\frac{1}{8}$ inch, $\frac{3}{16}$ inch, or other draft, right or left as may be required. It will readily be seen that whatever may be the width of the surface to which the bevel is applied, the taper or draft will be in the exact proportion of the given amount for each 12 inches.

Finish. The term *finish*, in pattern making, refers to the additional amount, after shrinkage and draft, which must be added to the pattern in places where the casting is to be planed, turned, chipped and filed, or "fitted," in the machine shop. The amount that is to be so added is, to a certain extent, though not wholly, independent of the size of the piece. For small articles whose longest dimension does not exceed three or four feet, an addition of $\frac{1}{8}$ inch to the surface to be finished is usually sufficient. For larger dimensions it may be necessary to add as much as $\frac{1}{4}$ inch or $\frac{3}{8}$ inch, but very rarely more than this. In making this allowance it is also well to bear in mind the tendency of the casting to warp in cooling. Where the thickness of the metal varies to any great extent, there is a greater liability to warp than if a uniform thickness prevails throughout the whole. Hence, in such cases, a greater allowance must be made for the finishing.

On small pieces and where the moulding is carefully done it may be possible to make as small an allowance as $\frac{1}{16}$ inch, but as a general rule sufficient metal should be put upon the casting to allow



WOOD LATHE.
Oliver Machinery Company.

the cutting tool of the finishing machine to cut well below the surface so that it shall not become dulled by the sand and hard scale on the outside.

A pattern for the plain cast-iron bar illustrated in Fig. 136 will afford a good example of the allowance necessary for finish and for draft. This bar is to be finished all over, the finished sizes being 36 inches long, 1 inch wide, and 1 inch thick.

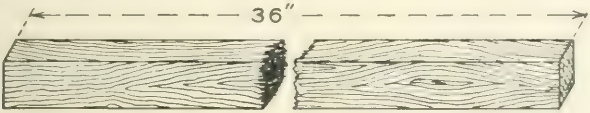


Fig. 136.

A slender bar of this length is liable to warp or bend when cooling in the mould, and for this reason the bar should have an allowance of at least $\frac{1}{8}$ inch all over for finish, thus requiring a pattern $36\frac{1}{4}$ inches long, $1\frac{1}{4}$ inches wide, and $1\frac{1}{4}$ inches thick. Moreover, to enable the moulder to remove the pattern from the sand without injury to the mould, we must add on two of the opposite sides a draft of about $\frac{1}{4}$ inch to the foot, making a cross-section through the pattern of the shape and dimensions as shown in Fig. 137.

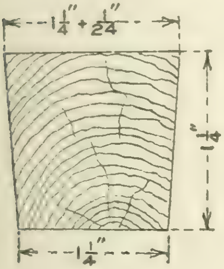


Fig. 137.

When accuracy is required in testing bars 36 inches × 1 inch × 1 inch (which are seldom finished), they are often moulded partly in the cope and partly in the drag, as shown in Fig. 138, the parting being on the line *a b*. In this position the inclination of the sides of the pattern in the mould is so great that no draft is required, the pattern being simply a square bar of wood of dimensions of 36 inches × 1 inch × 1 inch, measured with the shrinkage rule.

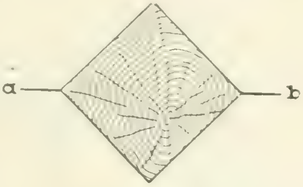
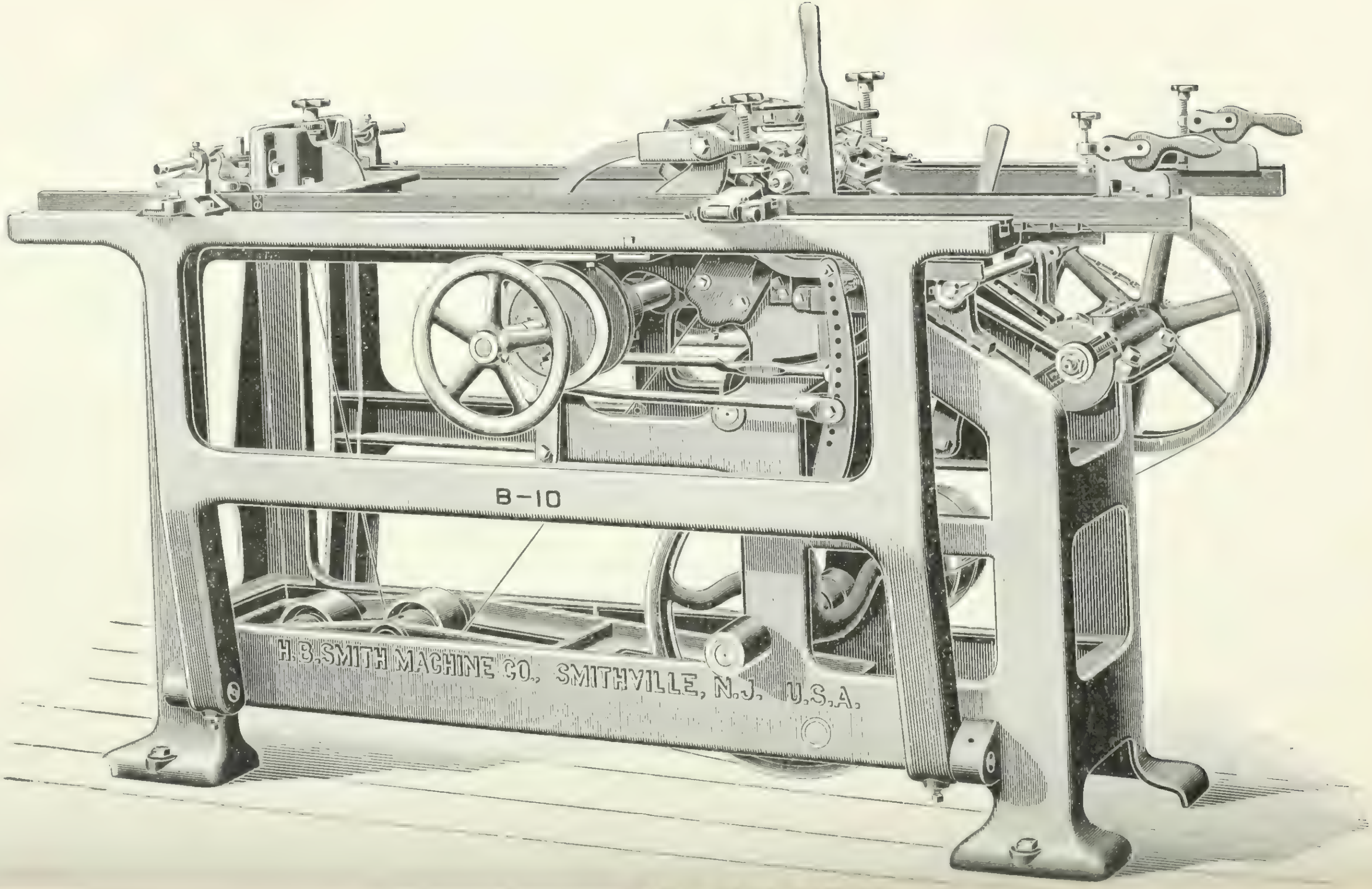


Fig. 138.



DOUBLE MORTISING AND BORING MACHINE

PATTERN MAKING.

PART II.

SIMPLE PATTERNS.

The simplest patterns are those which are made in one piece, and which require no coring, although the castings themselves may be hollow.

The first thing which the pattern maker should decide in commencing a pattern, is the way in which it is to be removed from the sand, and where the parting line, if there is one, should be. As an example of a simple pattern of one piece made without a dry-sand core, the stuffing-box gland (shown in Fig. 134, Part I) is a good illustration. It is readily seen that if the pattern of such a gland were to be imbedded in sand, as shown, there is no reason why it could not be lifted out without disturbing any of the surrounding or the internal sand. The drawing represents the pattern with *draft* and *finish* added, the finished gland being shown by the dotted lines.

In every pattern of this kind, forming its own core, it is necessary to allow double draft on the inside, so that the pattern may be rapped and removed without injury to the green-sand core, which at best is not very stable, and which should be used only when the gland or other hollow casting is of such size as to give a large and stable core.

Except in a few special cases, it is much better to put core prints on the ends of the pattern and use a dry-sand core in place of the green-sand core illustrated above, thus avoiding the unnecessary waste of metal added by the double draft on the inside of the casting, and the expense and labor of removing it in the machine shop.

In order to give a better understanding of the methods employed in Pattern Making, the object itself will be illustrated; and when it is to be finished, the finished dimensions only will be given. If the object is not to be finished, the sizes of the completed castings will be shown. These dimensions will, in all cases, be arbitrary, and can be changed at will, if for any reason alteration is necessary. The successive steps in the construction of the pattern are given in detail so that the student may fully understand the principles involved.

The first article for consideration is the *brass bushing* flanged at one end, illustrated in Fig. 139. This bushing is to be finished *all over*, and as the casting is small, $\frac{1}{16}$ inch will be sufficient for outside finish and the same for turning out the inside. On examining it with regard to moulding, we find that if moulded on end with the flange up and on the parting line of the flask it can be readily removed from the mould.

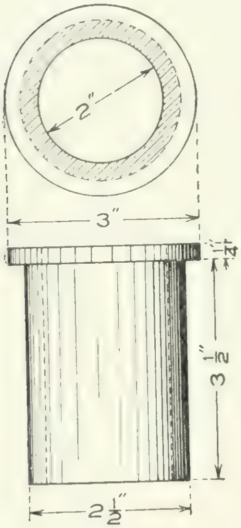


Fig. 139.

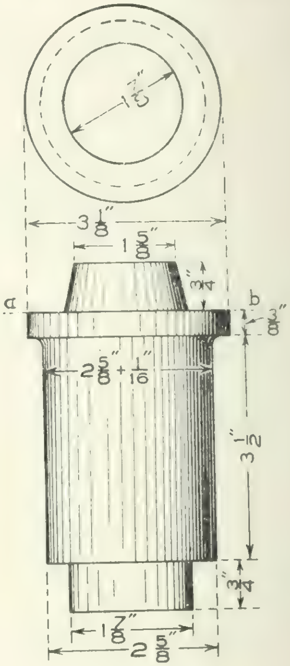


Fig. 140.

The draft in this case should be $\frac{1}{8}$ inch in 12 inches or a little less; and each core print, because the pattern is very short, need not be more than $\frac{3}{4}$ inch long. Having the finished sizes given (Fig. 139), and having decided on the amount of draft and finish, the pattern will be as represented by Fig. 140, and in the case of this simple pattern, as in all others, a full size drawing, or sketch, giving all the dimensions of the pattern, should be made by the pattern maker before beginning work on the pattern. This is good practice, and if carried out many mistakes and much loss of time will be avoided.

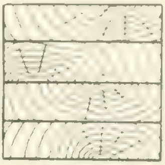


Fig. 141.

The lower core print should have the same proportion of draft as the body of the pattern, but the upper core print is given the excessive draft of $\frac{1}{8}$ inch to its length so that the cope can be easily lifted off and returned again over the tapering end of the dry-sand core without injury to the mould; the parting of drag and cope being on the line *a b*. This pattern may be turned from a solid block of wood, but if durability is desired the block should be glued up from 4 pieces of $\frac{7}{8}$-inch pine, care being taken to reverse the annular rings or yearly growth of the wood, as shown in Fig. 141.

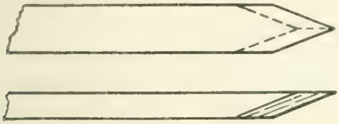


Fig. 142.

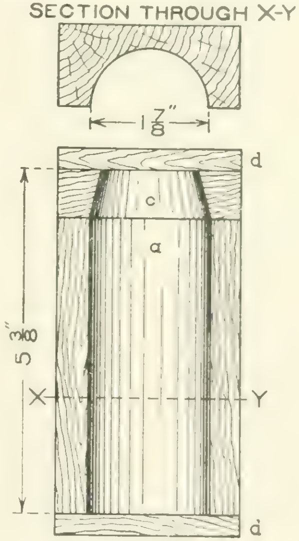


Fig. 143.

Place the block in the lathe and with the gouge turn to a cylindrical form of slightly greater diameter than the largest diameter of the pattern, say $3\frac{3}{16}$ inch. All finishing should be done by the use of scraping tools. For the body of the pattern, a firmer chisel 1 inch wide is a good tool, but the cutting edge must be ground and sharpened slightly rounding, as described for plane irons; otherwise the corners of the tool are liable to catch and form grooves on the surface.

For smoothing and finishing the ends of the pattern and flange, a diamond-pointed scraping tool, Fig. 142, is preferred to all others. The core box for this pattern is shown in Fig. 143, which is representative of the half box used for all symmetrical cores. In this box, two semicircular or half cores are made, which, after being dried, are pasted together, forming the cylindrical core required. For the part *a* of the core box, a block of slightly greater length ($\frac{1}{2}$ inch or 1 inch) is first planed up to the exact size. A center line *b*, Fig. 144, is drawn with the marking gauge parallel to one of the edges, and also extends across each end of the block. From this center line, at a distance of $\frac{15}{16}$ inch on each side, the lines *d* and *e* are also drawn. Then with a second block, or strip of wood placed against the face of the block and flush with the end, the two pieces are clamped together in the bench vise, as shown in Fig. 145. Now with the dividers adjusted to $\frac{15}{16}$ inch, describe on each end of the block the semicircle which will connect the lines *d* and *e* on the ends of the block. This wood may be removed rapidly with a gouge and mallet, smoothed with a round plane of proper size and curve, and finished by sand paper rolled on a cylindrical block having a diameter $\frac{3}{16}$ inch less than the width of the required box.

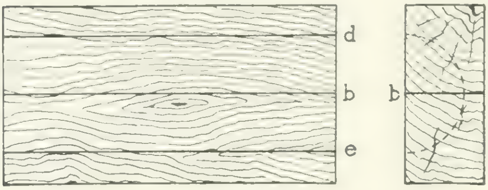


Fig. 144.

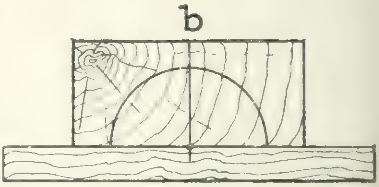


Fig. 145.

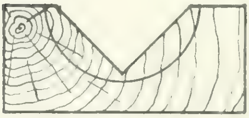


Fig. 146.

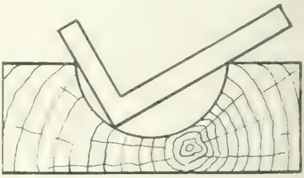


Fig. 146*a*.

Another method frequently used for small boxes, is to work out the center of the curve with a rabbet plane, forming a right-angled opening, as shown in Fig. 146, the remaining wood being removed with the round plane and finished with the cylinder and sand paper as before.

As the work progresses, the accuracy of the curve is tested by means of a try square, or other 90° angle, as shown in Fig. 146a.

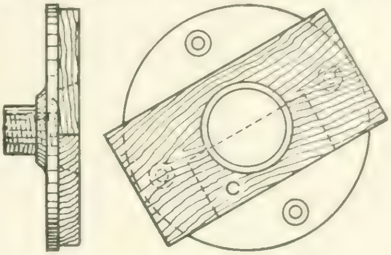


Fig. 147.

The tapered end of the box *c* (Fig. 143) is turned from a block of wood, screwed to the face plate of the lathe as shown in Fig. 147. After the hole is turned to the required depth, ¾ inch, and to the required size, 1⅞ inches on the outside, and 1⅝ inches at the bottom, it is removed from the face plate and the piece *c* is cut out, as shown by the dotted lines in Fig. 147. This piece *c* is glued and nailed to the end of *a*. The two ends of the box are now given a slight draft, (¼ inch in 12 inches) to allow the half core to leave the box easily. The end strips *d* and *d* (Fig. 143) are then nailed on and the box is complete.

FINISHING PATTERNS.

Having completed the pattern and its core box, the surface of the wood must be covered with some material which will render it hard, smooth, and impervious to the moisture in the sand, and at the same time make it easier to be withdrawn from the mould. Pure grain-alcohol shellac-varnish is the best for this purpose. All cheap substitutes, such as wood-alcohol shellac, or copal varnishes should be avoided. They become flaky and scale off, and do not stand the exposure and moisture. Pattern makers generally make their own shellac varnish, buying only the best quality of shellac gum, and using 95 per cent proof alcohol. The proportions are three pounds of gum to one gallon of alcohol. The gum is put in a wide-mouthed bottle, or earthen jar, and the alcohol poured over it, and if well stirred three or four times during the day will (if the alcohol is of the best,) give a smooth, clear, orange-colored varnish ready for use.

A good grade of "white grain-alcohol shellac" may be made from bleached gum, or can be bought from the dealers, but it dries more slowly and does not produce so hard a surface as the orange shellac.

As the alcohol in shellac-varnish evaporates very rapidly, the brush should be kept in a vessel which is closed and air tight. A short bottle having a mouth wide enough to admit the brush is best for this purpose. A one-inch, flat, double-thickness, fitch-hair brush is good for general work. Do not use a cork, but turn a wooden cap for the bottle, such as is shown in Fig. 148. The shoulder at *a* may be $\frac{3}{16}$ inch to $\frac{1}{4}$ inch long, but must be at least $\frac{1}{4}$ inch less in diameter than the inside of the mouth of the bottle. Otherwise the shellac will cement it to the glass so that it cannot be removed. Its only object is to keep the cap nearly central on the bottle. The handle of the brush must be tightly fitted into a hole through the center of the cap and fastened with a screw or brad; allowing the brush to reach within one-half inch of the bottom of the bottle. Keep the bottle one-third to one-half full of shellac and use the brush with the cap on the handle. The shellac will make a tight joint between the bottle and the cap, and if the proper amount of shellac is kept in the bottle, the brush will always remain soft.

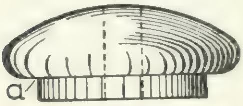


Fig. 148.

For small patterns, such as the bushing described, the small quantity of shellac needed can be used directly from the bottle. For large work however, an earthern-ware cup or mug should be used, but the shellac left over should always be returned to the vessel in which it is kept.

Shellac varnish should never be kept in a metallic can or cup, as the oxidation of the metal will discolor the varnish.

Having given a perfectly smooth surface to the pattern and core box by the use of very fine sand-paper, (No. 0) apply the first coat of shellac. This first coat will raise the grain and roughen the surface of the wood, which, after the shellac is perfectly dry, must be sand-papered a second time until smooth. Now apply a second coat. Should there still be roughness, a second sand-papering will be necessary. At least three coats of shellac should be used. If there is much end wood exposed on any of the surfaces of the pattern, a fourth coat may be necessary on these parts.

As regards the color in which patterns are finished there are different rules in different shops. The general rule, however, is to leave all patterns for brass or bronze, in the natural color of the wood, and shellac the core prints red. If the pattern is intended for moulding cast iron, the body of the pattern is made black and the core prints red. The parts of the core box in which the core is to be formed are also colored red and the outside of the core box black. The black color is produced by mixing lamp black with the shellac varnish, and the red color by mixing vermillion (Chinese is the best) with the shellac. The vermillion is heavy and will settle, hence it must be stirred or well shaken before using. The best method is to first use two coats of the natural colored shellac (orange or white) on all surfaces of the pattern, core prints and core box, then apply the black or red for the last coat only.

As the pattern already described is for a brass bushing, the body should be left the natural color of the pine, and the core prints on the pattern and the inside of the core box colored red.

The outside of the core box may be left the natural color or made black, as preferred. The outside of the core box, having no part in the formation of the core, is not necessarily so well and smoothly finished as the inside.

All nail holes or any defects in the wood should be filled with beeswax applied with the warm blade of a knife, or narrow chisel, warmed by holding in hot water. The beeswax should always be used after the first coat of shellac has been applied, as it will then hold better. The sand-papering of the pattern, after the first coat. will smooth the wax and bring it even with the surface of the wood. The time required for a coat of shellac to dry is from eight to twelve hours, depending upon how heavily it may have been applied, even though to the touch the surface may seem dry in one or two hours.

If a hard, *durable* surface is required on the pattern, twelve. or better, twenty-four hours must be given between each coat. The roughness will then sand-paper off as a dry powder without gumming the sand-paper, and leave a hard, smooth surface for the succeeding coat of shellac.

The second casting to which attention is called, is the *brass bearing* represented in Fig. 149, which is to be finished all over. On examining the drawing, first with regard to removing the pattern from the sand, we find that it must be moulded on its side, and that the moulder may not lose time in cutting away the sand (see Figs. 113 and 114, Part I) the pattern must be *parted*, or made in two halves.

For finish on this small pattern $\frac{1}{16}$ inch will be sufficient, and draft will be required only on the ends of the pattern, and on the ends of the core prints, which in this case, should be not less than 1 inch long. This is necessary, because the core-print moulds must sustain the weight of the dry-sand core.

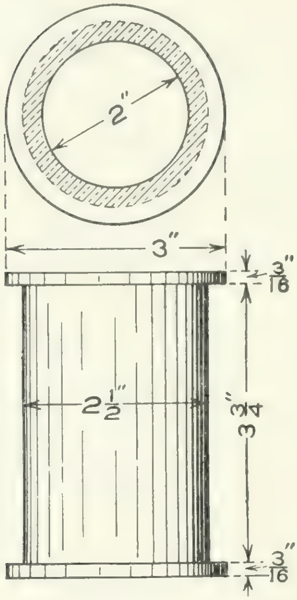


Fig. 149.

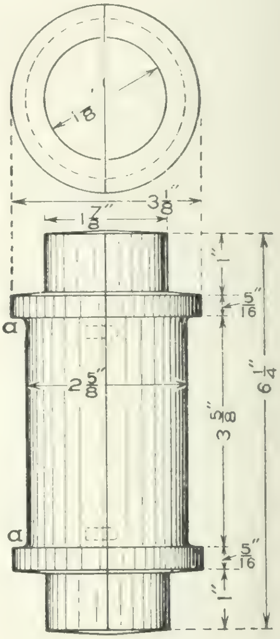


Fig. 150.

The pattern for this casting is represented by Fig. 150, in which it is seen that, unlike Fig. 140, the body and core prints are perfectly straight, a slight draft $\frac{3}{16}$ inch to 12 inches being given to the ends of the pattern and to the ends of the core prints only. A slight curve of $\frac{1}{16}$ inch radius should also be made at the intersection of the body of the pattern, and the inside of the flange at *a*, *a*.

The wood in being prepared for this pattern should be cut $2\frac{1}{2}$ inches longer than the finished pattern. The dimensions of the two halves would each be $1\frac{3}{4} \times 3\frac{3}{8} \times 8\frac{3}{4}$ inches. Having fitted the two insides accurately together and dressed one edge of each straight and at right angles to its face side, with the marking gauge, draw a center line on each, not only on the face but also across each of the two ends, Fig. 151. Across the center of each piece draw, with a sharp-pointed knife and try square, a second line at right angles to the first and at equal distances from each end of the block. With dividers adjusted to $1\frac{7}{8}$ inches, place one leg at the intersection of the two lines, and on the gauge line mark two dots, each $1\frac{7}{8}$ inches from the center line. These dots are the centers for the dowels which are to connect the two halves of the pattern after it is finished. Bore the holes in each piece $\frac{1}{2}$ inch deep with a $\frac{5}{16}$ inch auger bit, and cut the dowel pins only $\frac{3}{4}$ inch long, gluing them into the holes of one piece and giving a projection of $\frac{1}{4}$ inch to fit in the holes of the second half of the pattern. Although the dowels are glued into the first half they must fit easily, but not loosely, in the second, and should be rounded on the ends or made cone shaped, as in Fig. 152.

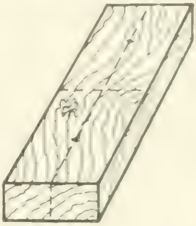


Fig. 151.

Having fitted and prepared the two blocks with their dowel pins, carefully glue them together using only a narrow strip of glue $\frac{1}{2}$ inch wide on each end of the block and clamping the two together with a hand screw on each end. When the pressure of the hand screw is applied, the glue will spread inward to $\frac{3}{4}$ inch or 1 inch. Great care must be taken not to use too great a quantity of glue, or it will spread in far enough to bind the two halves of the pattern together so that they cannot be separated when turned and finished. The blocks should remain in the hand screws, after

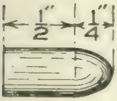


Fig. 152.

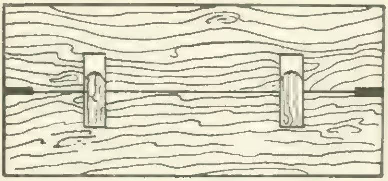


Fig. 153.

being glued, from four to six hours, depending on the temperature of the room in which the gluing is done. Our pattern block is now ready for the lathe and will be as represented in Fig. 153, which is a longitudinal section through the dowel pins.

When centering for the lathe centers, great care must be taken to mark the centers exactly at the intersection of the center-gauge lines on the ends of the blocks and the glued joint of the two pieces. The hard glue will force the lathe center to one side of the connecting joint unless a center dot or hole is first made with an awl in the exact position required. As in the case of the pattern in Fig. 140, the block is roughly turned to dimensions, all of which are a little larger than the finished pattern, by using the ordinary turners' gouges, but the final turning and finishing to exact sizes must in all cases be made with scraping tools, as described for the pattern of the *brass bushing*.

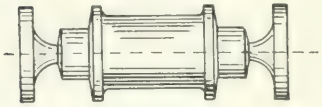


Fig. 154.

When marking off the pattern on the rounded cylinder in the lathe, care must be taken to locate the pattern in the exact center of the block, so that the dowel pins may be equally distant from each end and from the center of the pattern. Fig. 154 shows the pattern as ready to be taken from the lathe. The core print ends should be cut down to $\frac{3}{4}$ inch at each end, and finally cut off with a saw, and the ends finished with file and sand paper after removing from the lathe, when, as will be seen, the glued end having been cut off, the two halves of the pattern will separate clean and free from glue, and the dowel pins will always bring them into accurate alignment when used by the moulder in the foundry. Before removing the turned pattern from the lathe, it should be smoothed and finished with sand paper, but care must be taken not to allow the sand paper to come in contact with the sharp corners and angles of the pattern, or they will be rounded off and the work ruined. For pine, only the finest paper, No. $\frac{1}{2}$ and No. 0 should be used on lathe work, and the paper must not be held in one position on the revolving work but must be kept moving laterally, that is, from side to side, to avoid cutting depressions in the surface.

When the scraping tools are kept sharp so that they will cut freely and without pressure, a light touch of sand paper only will be required.

In the construction of this pattern, it may be made of two blocks of 1¾-inch stock as described; but the tendency of the two halves will be to become rounding on the parting line as shown by the dotted lines *c d* and *e f*, Fig. 155. This is caused by the removal of considerable wood in the process of turning, at the angles *a a a a* thus exposing fresh surfaces which are farther removed from the original surfaces of the plank, than the surfaces on the line of parting. The exposure of these deep, inside fibers of the wood will cause a shrinkage of the pores and draw the pattern more or less, according to the position of the annular growths, and also to the more or less thorough seasoning of the wood, in the direction indicated. If the pattern is intended for temporary use only, it may be constructed as above, but if durability and permanence of shape are required, the two blocks should each be glued up out of thinner stock with the annular growths carefully reversed, as shown in Fig. 156. This is done not only because thin plank is more evenly and better seasoned, but because in gluing, the tendency of the pieces to warp or spring is counteracted each by the other, and in addition the gluing of several thin pieces together

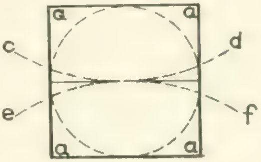


Fig. 155.

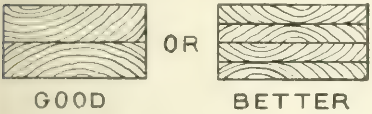


Fig. 156.

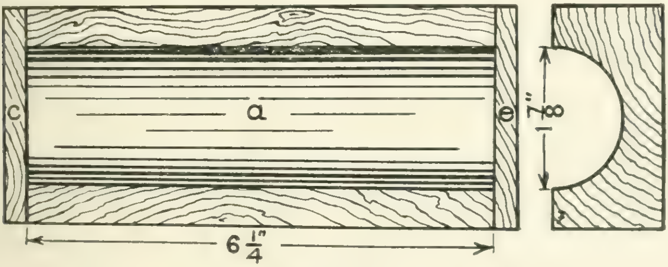


Fig. 157.

stiffens and makes the resulting piece much firmer and stronger than a large block or piece of the same size obtained without gluing.

The core for this pattern, being straight from end to end, and cylindrical, only a half core box is required, as shown in Fig. 157. After being laid off and worked out in the same manner as described for the core box, Figs. 143 and 144, cut the ends of *a* with draft of $\frac{1}{4}$ inch in 12 inches, and glue and nail on the ends *e* and *e*, which may be $\frac{3}{8}$ inch to $\frac{1}{2}$ inch in thickness.

Shellac and finish as described for pattern, Fig. 140, giving first two coats of orange or white shellac, and for the last coat on core prints of the pattern and the inside of the core box *a* use the red, the body of the pattern being left natural color (with three coats) and the outside of the core box either natural or black.

GLUING.

As the use of glue enters largely into the construction of all patterns, some instruction as to its selection and the manner of using will be necessary. When building up patterns, the connections should in all cases be made by gluing. Nails should never be used except when they can be so placed as to be entirely removed from all danger of contact with the tools used in turning and shaping the pattern, and when so employed should be used in conjunction with glue. The only advantage in their use is the hastening of the work, because they take the place of hand screws or clamps while the glue is drying.

The use of nails, however, is always unsatisfactory, for when the point is passing through the upper piece, small thin slivers are broken from the under surface, which have a tendency to separate the two surfaces instead of exerting the required pressure as when hand screws are used.

For pattern work select only the very best quality of cabinet-makers' glue, or better still, the best quality of white glue. This white glue can always be had in two forms, first, white glue, *clear*, and second, white glue *opaque*. The first is the glue without the addition of any foreign substance. The second looks much whiter than the first, because of the addition of whiting, or other mineral, to the glue. This addition does not in any way lessen the adhesive qualities of the glue; on the other hand, it sets more readily and dries more quickly, but for this very reason, it is harder to use on large surfaces, as the first brushing on one part of the work will begin to set before the entire surface can be covered. For all small or moderate-sized work, however, the opaque, white glue is to be preferred.

Good glue will keep in a dry room of any temperature for an indefinite length of time, but when cooked in the glue-pot it deteriorates very rapidly. Each successive reheating and boiling lessens its adhesive qualities, hence it should always be used *fresh* or nearly so. A greater quantity of glue than is likely to be used in two or three days should not be cooked at one time.

The cooking and preparing must be done in the regular glue-pot, made for the purpose, and sold in all hardware stores. No rule can be given for the relative quantities of glue and water to be used. Some glues, especially the cheaper grades, require much less water than the better and finer qualities. As a general rule however, pack the glue firmly in the pot and add sufficient cold water to cover it. Fill the outside kettle with cold water and boil until thoroughly cooked, so that it will run smooth and clear from the brush or paddle. It should run freely without returning and gathering in bunches or clots at the end of the paddle, but must not be so thin as to be weak and watery.

If the glue is too thick, no amount of pressure will bring the two glued surfaces in close contact, and if too thin there is danger that the joint will not hold. Always use cold water for cooking and dissolving fresh glue. Hot or boiling water will make the glue *stringy* and will require a much longer time to cook to an even and smooth consistency. Great care should also be taken to keep the outside kettle, which surrounds the glue-pot proper, full of water. If allowed to *boil dry* the glue in the inner pot will be scorched, or burned, and will then be entirely useless. It must then be thrown out, the pot washed or boiled out clean, and fresh glue again cooked. The hot water in the outside kettle should in all cases be used for thinning the glue to the required consistency. Cold water chills the glue and necessitates reheating. In cold weather the precaution must be taken, unless the room is warm and entirely free from drafts, to heat the pieces of wood before applying the glue, else the latter may be chilled and fail to set. The time required for well-made joints to dry so that the hand-screws can be removed is from four to six hours.

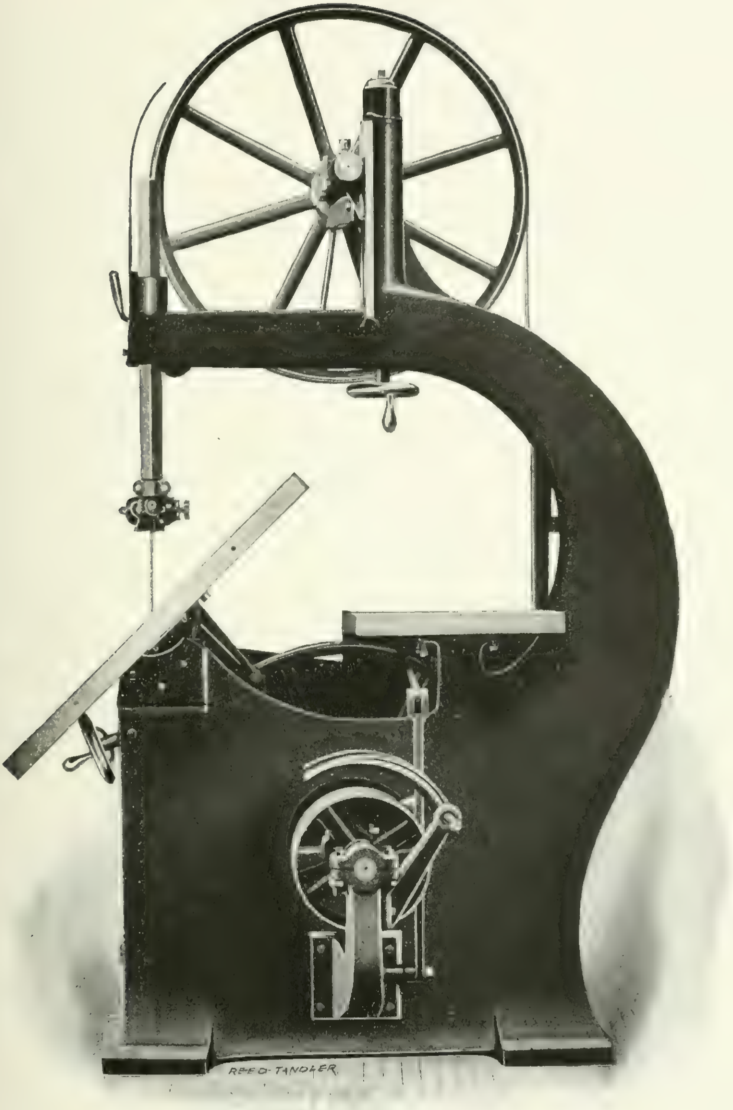
Sometimes a difficulty will arise in the case of large surfaces on thin material. When the glue is applied it moistens and expands the surface upon which it is placed, causing the edges to curl up and pull away from the adjoining piece which has a tendency to move in the opposite direction. In such cases *never* moisten the back of the thin pieces with water from the outside kettle, as is sometimes directed, but work quickly, spreading the glue rapidly and then place between two thick, stiff pieces of board, previously dressed true, prepared and heated for the purpose. Use as many hand-screws as can be conveniently placed on the work, and allow it to remain in these clamps until all moisture from the glue is absorbed by the two outside, heated boards. Twenty-four, or better forty-eight, hours should be given to this process if possible.

All such gluing of thin pieces should in every case be done first and allowed to dry while the other parts of the pattern are being constructed. Under no circumstances use water on any surface of seasoned wood. The reseasoning or drying out of such water will invariably distort, curl, and warp the pieces so treated after being glued together. Even the water contained in the glue is objectionable, while unavoidable, and can be most satisfactorily removed only as directed above.

In all cases where end wood is to be glued, or where the grain of the wood runs diagonally to the plane of the joint so as to present the open end wood pores for the glue, this end wood, or partially end wood joints, should be first "*sized*" with thin glue, (glue about half the thickness of that used for gluing,) and allowed to dry. This will raise the grain and roughen the surface of the joint, which, when dry, must be lightly and carefully scraped off with a sharp chisel, when it will be found that the open pores of the wood are filled with dried glue. The joint may now be glued, and the glue will hold as in ordinary jointing.

HAND SCREWS.

The hand screws, illustrated in Fig. 81, enter so largely into all gluing for pattern work, that some description of their con-



BAND SAW.
Oliver Machinery Company.

struction and the manner of using is necessary here. The four parts of each hand screw consist of two *jaws* and two *spindles*. When using, the *jaws* must in every case be kept parallel. This is done by the adjustment of the middle or central spindle. The clamping is in all cases done by the outside or end spindle, the middle or adjusting spindle serving as a fulcrum for the jaws; the leverage and pressure being obtained by the end spindle. When clamping broad surfaces, care must be taken to see that the pressure of the jaws on the work being glued is the same at the points and at the back part of the applied portion of the jaws.

This can be easily changed at will, by slightly loosening or tightening the middle spindle, which, as before stated, is the adjusting spindle and fulcrum, and not used for clamping. After adjusting the jaws parallel and to even pressure on all their length as applied to the work, screw up and tighten the end spindle to the utmost pressure which the jaws will bear, and again examine the clamp and the work to see if the jaws are parallel and the pressure even.

If not, loosen the end spindle and readjust the middle spindle by opening or closing as the case may require. To open and close the hand-screws for larger or smaller work, *do not* screw or unscrew *one* spindle at a time. Instead, grip the handle of the *middle* spindle in the left hand, and the handle of the end spindle in the right hand. Hold the hand screw at arms length and whirl it from or toward you as may be needed for closing or opening the jaws. In this way the spindles will each be kept in its proper relative position, and the jaws will, at all distances, remain parallel.

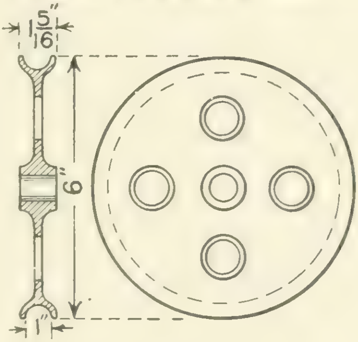


Fig. 158.

BUILT UP PATTERNS.

A good example of the manner in which patterns are built and glued up is shown in the construction of the pattern for the 6-inch sheave pulley shown in Fig. 158.

The groove is a semicircle 1 inch wide, and the rim containing the groove is connected with the hub by a solid web ¼ inch in thickness, and having four or six holes, each 1 inch in diameter, this web taking the place of arms. If there is to be no *finish* on the sheave, as is usual, the only allowance to be made on the pattern, *which must be parted*, will be for shrinkage and for draft.

A cross-section through the finished pattern for this casting is shown in Fig. 159.

In all large patterns of this kind, the web is first glued up in sectors, six, eight or more in number, according to the size of the sheave (see Fig. 160). The sectors are fitted by hand or on the trimmer, the ends are glue-sized, and when the sizing is dry the joints are carefully scraped smooth, and the whole glued together. After drying for four or five hours, it is sawed to a circle of ½-inch greater diameter than the finished pattern, and the block for the hub is glued over the center. Six segments to form the outer rim are glued around on the outer edge, care being taken to *break joints* as shown in Fig. 161. If the groove is to be large, the six segments should be of half the thickness only, and a second set of segments of like thickness glued over the first, *breaking joints* not only with the first set, but also with sectors of the web.

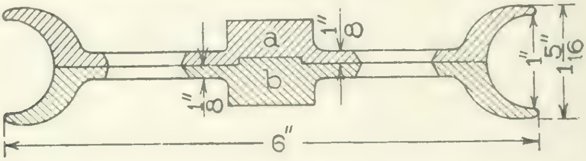


Fig. 159.

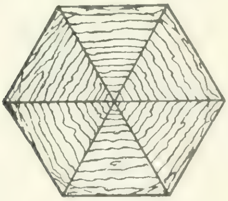


Fig. 160.

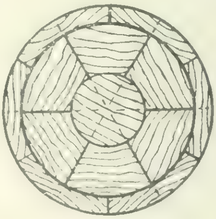


Fig. 161.

In other words, in all glued-up rims, no two joints should be directly over each other. All joints must be so *broken* and so distributed as to give the greatest possible strength to the rim. In the present case, our pattern is so small that it is only necessary to use a thin board, ¼ inch in thickness for each half of the web. After sawing to 6½ inches in diameter, ½ inch for turning, a block ½ inch in thickness is glued on the center of each to form the hub; and six segments 1¼ inches wide and ½ inch in thickness, are glued around on the outer surface of each to form the rim and groove, as shown in Fig. 162.

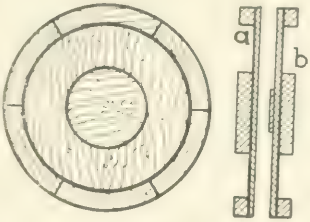


Fig. 162.

Care must be taken to place the segments so that the grain of the web will be crossed by two of the segments as shown in the drawings.

On the second half *b* of the pattern, a thin circular block ¼ inch in thickness is glued on the inside opposite to the hub block, to form the projection (⅛ inch) which will keep the two halves of the pattern in alignment, as shown in the cross-sectional drawing in Fig. 159. Having glued up the stock as described, and as shown in Fig. 162, the outside must be planed to a level surface, or so that the six segments forming the rim and the center hub block will be in the same plane.

The half pattern is now screwed on the screw chuck of the lathe as illustrated in Fig. 163, and the inside, or the parting face *c*, is turned perfectly straight and true. The edge is turned down to 6 inches in diameter, and the quartered circle shown by the dotted lines is carefully shaped. A template, made as shown at *d*, will assist greatly at this stage of the work. A recess is turned at the center, and in the face of *a*, Fig. 159, 1½ inches in diameter and ⅛ inch deep, to receive the corresponding projection on the half pattern *b* which is to keep the two halves in alignment.

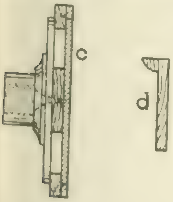


Fig. 163.

The half pattern *a*, is now removed from the screw chuck, and the second half *b* is screwed on and turned in the same manner except that the central projection is carefully turned to fit in the recess in *a*.

Before removing *b* from the chuck, test by trying the second half *a*, and change *b* until a perfect fit is obtained between the two halves, not only in the central recess and projection, but also in the two curves which form the semicircular groove of the rim. A cross section of the pattern at this stage of construction is shown in Fig. 164.

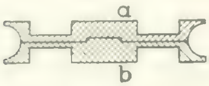


Fig. 164.

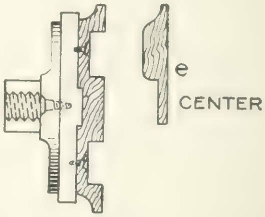


Fig. 165.

A disc or chuck of wood 5½ inches in diameter is now screwed to the iron face-plate, or the screw chuck, and turned off true on the face with a projection ⅛ inch high which will fit into the recess in the middle of the parting face of *a*. This projection will center the half pattern *a* on the face plate, and it can be held in position by two or four short wood screws driven through the web into the wooden chuck as shown in Fig. 165.

Care must be taken to place the screws in such a position that the screw holes will be cut or bored out when making the four or six openings 1 inch in diameter in the finished web of the pulley.

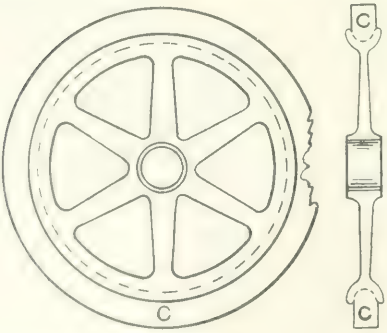


Fig. 166*a*.

The screws must be small and slender and the heads well countersunk out of reach of the turning tools. The face of the half pattern is now turned to the required shape, the template shown at *e* in Fig. 165, being used for the purpose. Having finished with fine sandpaper, remove the half pattern, and turn off the projection on the center of the wooden chuck; turn a recess instead to receive the projection on *b*, and proceed with this second half as with the first. If the wood has been well seasoned, and the work carefully done a perfect 6-inch sheave pulley pattern will be obtained, such as is shown in Fig. 159.

The pattern for a sheave pulley has been explained because it embraces so many profitable points and conditions, not only in gluing and building up, but especially in chucking and turning, all of which must be done with great care and accuracy.

The 1-inch holes in the web are bored out with a 1-inch *center bit*, which, when well sharpened, will not split or splinter the thin webs of the two halves of the pattern, if care is taken to reverse the bore from the opposite side when the point of the center bit comes through. The holes should be given a slight draft as shown in Fig. 159, with a small half-round cabinet file. When very large sheave pulleys, having arms, are to be made, such as are common for power transmission by rope or cable, the patterns are not halved but are made in one piece and the groove is *cored* around the rim. Such a pattern is illustrated in Fig. 166*a*, with a wide core print *c c* extending entirely around the periphery of the pattern.

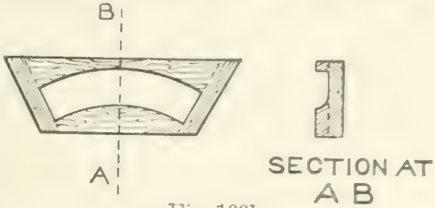


Fig. 166*b*.

A segmental core box is made for one sixth or one eighth the circumference of the wheel, as shown in Fig. 166 *b*, and here again only half of the core box for a full core is needed. When coring the rim as above, the core print must be made wide, at least two to three times the depth of the groove, so that the core may rest firmly and remain in position without tilting while the metal is being poured into the mould.

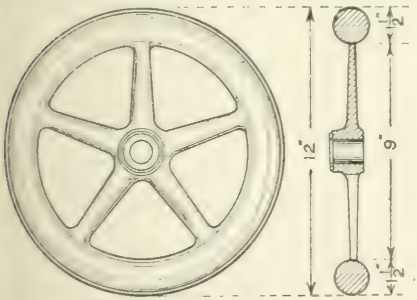


Fig. 167.

The 12-inch hand wheel, Fig. 167, with five arms and a round rim finished to $1\frac{1}{2}$ inches in diameter, will also serve as a good illustration of pattern construction. On the rim of the pattern, $\frac{1}{16}$ inch over all its surface must be allowed for *finish*, making the diameter of the rim of the pattern $1\frac{5}{8}$ inches, and the outside diameter of the pattern $12\frac{1}{8}$ inches, while the inside diameter of the rim will be $8\frac{7}{8}$ inches.

The rims of such patterns are usually turned in two halves. A wooden chuck, in this case a plain board 12¾ inches in diameter, and ⅞ inch to 1¼ inches in thickness, is screwed to the iron face-plate of the lathe, and turned true on the face and on the edge to 12½ inches in diameter. Ten blocks 2½ inches long, 2 inches wide, and ¾ inch in thickness are glued radially at equal distances around the face of the chuck as in Fig. 168. These blocks are turned even with the edge of the chuck, and the faces are also turned off true and straight so as to form a joint with the first row of rim segments.

The segments, ten in number, five for each layer, are sawed from a ½-inch board, and should be 2 inches wide.

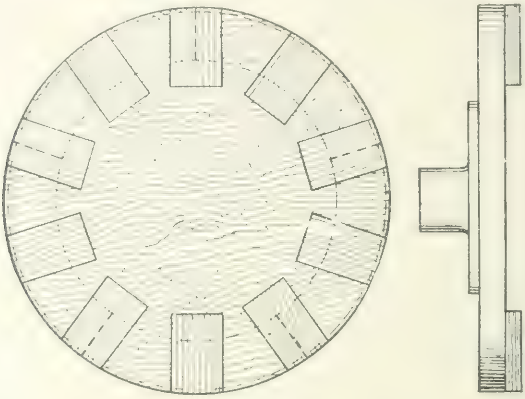
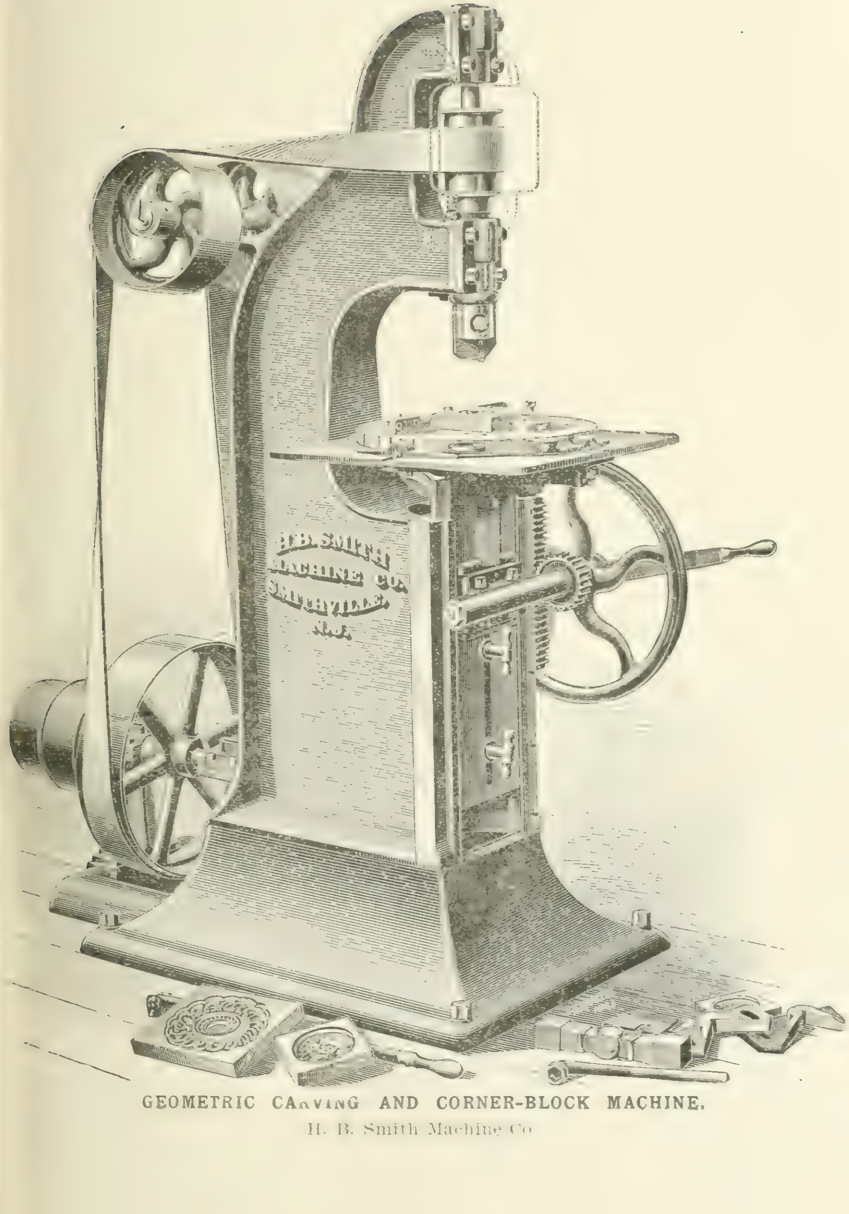


Fig. 168.

Five of these are carefully fitted and glued to the face of the blocks, as shown by the dotted lines in the drawing; and when the glue is dry the chuck is returned to the lathe, and the face of the segments turned flat and true to receive the second row, which is fitted and glued to the first.

Small hand screws must be used, three on each segment, to press the first layer to the blocks, and again to press the second layer to the first. The joints of the second layer must be over the middle of the alternate blocks from the joints of the first, so as to break joints with the first. When the glue is dry, place the chuck in the lathe, and turn the half rim thus constructed to a true semicircle with an outside diameter of 12½ inches and an inside diameter of 8½ inches, using a semicircular template of sheet zinc or copper to test by while turning.



GEOMETRIC CARVING AND CORNER-BLOCK MACHINE.

H. B. Smith Machine Co

When turned and sand-papered, cut from the block of the chuck by using a $\frac{1}{8}$-inch parting or cutting-off tool, care being taken to cut close to the segments forming the half rim. Turn off the face of the blocks on the chuck true and straight a second time, and construct and turn the second half of the rim in the same way as described for the first; but great care must be taken to make the two diameters, outside and inside, of each half exactly alike, otherwise the work on one half will be lost. As it is difficult to hold these two half rims for planing and fitting together, a concave and semicircular groove turned in the face of a second board, or chuck, in which they can be laid while being planed or fitted, will be found useful.

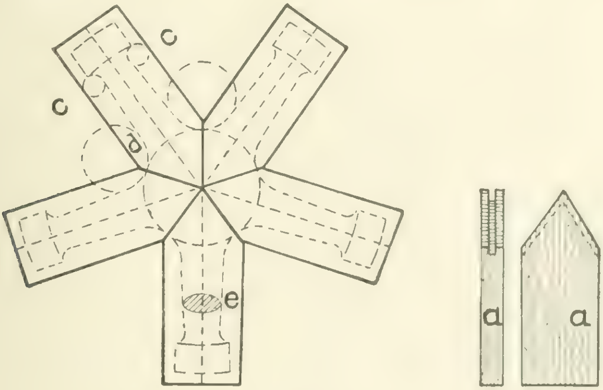


Fig. 169.

In all rim work of this kind the circular segments should be cut lengthwise with the grain of the wood, the object being in this construction, to do away, as much as possible, with all end wood.

While waiting for the separate layers of glued segments to dry, the arms should be made so as to be ready for the two half rims when completed.

The arms in this case should be made $\frac{5}{8}$ inch in thickness at the hub and $\frac{1}{2}$ inch in thickness where they enter the rim of the wheel. The construction is as shown in Fig. 169.

Five pieces, each $5\frac{3}{4}$ inches long, $2\frac{1}{8}$ inches wide, and $\frac{5}{8}$ inch in thickness are necessary. After being carefully fitted on the trimmer, a saw kerf $\frac{5}{16}$ inch deep is cut in each joint (*a*, Fig. 169), into which a thin tongue of wood is inserted and glued, the tongues serving as tenons to hold the arms together. After fitting, and before grooving with saw kerf, the joints must be glue-sized and, when dry, carefully scraped smooth with a sharp chisel.

The grain of the wood in the tongues must run at right angles to or crosswise of the joint to insure the greatest strength.

When glued together and dry, from the center or intersection of the five pieces, mark with dividers set to a radius of $5\frac{1}{4}$ inches, and cut off the ends of the arms so that they will project each halfway into the rim.

From the same center describe a circle $3\frac{1}{2}$ inches in diameter, forming the web of the arms; and from this $3\frac{1}{2}$-inch circle, taper the arms to $\frac{1}{2}$ inch in thickness at the ends, care being taken to plane the same amount from each side and to dress the arms evenly so that they will revolve in the same plane. This being done, from the center describe arcs on the outer ends of the arms, with a radius of $4\frac{3}{8}$ inches ($8\frac{3}{4}$ inches diameter, which is $\frac{1}{8}$ inch less than the inside diameter of the rim), and divide the imaginary circle thus formed into five equal parts with the dividers. Draw radii from the points thus obtained, to the center. These radii will be the central lines of the arms, as shown by the dotted lines in Fig. 169

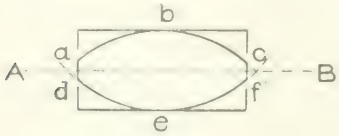


Fig. 170

Fig. 171.

On each side of the intersection of the radii and outer circle, measure $\frac{1}{2}$ inch to the right and left, and on the circle denoting the circumference of the web, mark $\frac{11}{16}$ on each side of the radii; connect the points thus obtained, and the result will be five arms $1\frac{3}{8}$ inches wide at the web and 1 inch wide at the rim, as shown in the drawing. The ends of the arms which enter the rim should be, in this case, $1\frac{1}{4}$ inches wide, and the sides are drawn parallel to the radius which marks the center of each arm. The curves which connect the arms at the hub must be drawn of such radius as to make the curve tangent to the circle forming the extremity of the web, and also tangent to the sides of the two connected arms as shown at *d*. The small circles at the intersections of the arms with the rim, must be tangent to the edge of the arm and to the circle ($8\frac{3}{4}$ inches diameter) which marks $\frac{1}{16}$ inch less than the inside diameter of the rim as shown at *c c*.

Having laid out the arms as above, and as shown in the drawing by the dotted lines, saw them to shape and round them up to an elliptical form as shown in the cross-section at *e*, Fig. 169. The finished shape of the arm at any point in its length, is found by drawing a cross-section of the arm at that point, as in Fig. 170.

Divide the cross-section equally by the line A B; measure $\frac{1}{16}$ inch; as at *a c d f*; and with dividers adjusted so as to be tangent to the sides of the cross-section of the arm, and to pass through *a c* and *d f*, draw the curves *a b c* and *d e f*.

After filing and working off the sides of the arms to these curves, the angles at *a c d* and *f* are carefully rounded with sand paper, care being taken not to lessen the width of the arm at any point. The result will be as shown in Fig. 171, which gives a strong, firm edge to the arm, and one which will not break or splinter off while being rammed up in the sand.

The arms thus shaped and finished are cut or *let* $\frac{1}{4}$ inch into each half of the rim, and great care must be taken to keep them central with the rim. Before marking the rim for the mortises which will receive the ends of the arms, test their positions with the dividers, spacing from the center of the arms to the outside edge of the rim, and moving the arms until a central position is obtained; after which, with the point of a knife or awl, scribe around the end of each arm, and proceed to cut, with a chisel, the mortises $\frac{1}{4}$ inch deep into each of the half rims, and so cut and fit that the two pieces of the rim may meet and form a close joint, after which they are glued and clamped together over the arms with hand screws.

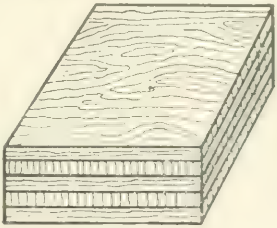


Fig. 172.

The hubs are next turned, each from a solid block, or better from thin pieces $\frac{1}{4}$ inch to $\frac{3}{8}$ inch in thickness, each thin piece being placed crosswise on the other, as shown in Fig. 172. The hubs must be turned with a draft or taper of $\frac{3}{8}$ inch to 12 inches, and have a curve of $\frac{1}{4}$-inch radius at the base where they unite with the arms. After gluing on the hubs, smooth off all connected parts of rim, arms, and hub, and finish with three coats of shellac, sandpapering smooth between each coat, as already described for other patterns.

The making of patterns for special pulleys enters largely into the work of many pattern shops. In these patterns the rims are built up of segments $\frac{3}{8}$ inch to $\frac{1}{2}$ inch in thickness.

To illustrate this work fully, let us take up the successive steps in the construction of a countershaft pulley 20 inches in diameter and of 6-inch face, made to fit a shaft $1\frac{3}{4}$ inches in diameter. The pattern for such a pulley is shown in Fig. 173. The diameter of the web of the arms is 5 inches, and the diameter of the hub $3\frac{1}{2}$ inches at each end and tapering to $3\frac{3}{4}$ inches in diameter at the arms.

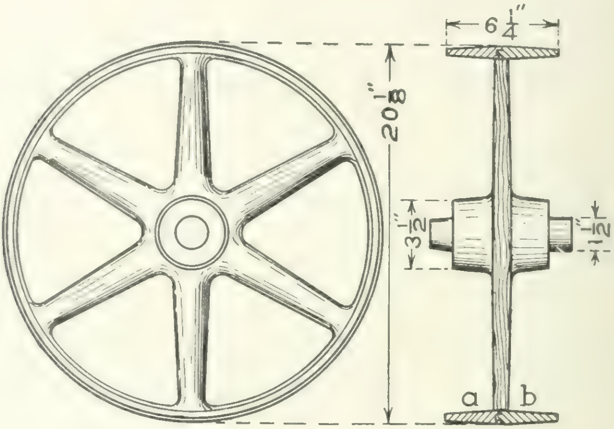


Fig. 173.

If the rim is to be finished on the face and edges only, $\frac{1}{16}$ inch must be allowed for turning, making the outside diameter of the pattern $20\frac{1}{8}$ inches, and the width of the face should be $6\frac{1}{4}$ inches.

In addition to $\frac{1}{16}$ inch for finish, the draft on the outside of the rim, from each edge to the center, should be in the ratio of $\frac{1}{8}$ inch to 12 inches, and on the inside of the rim the draft must be $\frac{3}{8}$ inch to 12 inches.

The thickness of the rim at its edges will be $\frac{5}{16}$ inch, and with outside and inside draft added, its thickness at the arms will be about $\frac{7}{16}$ inch. The inside diameter of the rim at the arms will be nearly 19[illegible] inches. This pulley should have six straight arms

¾ inch in thickness at the hub and ⅝ inch in thickness at the rim. The width of the arms at the web should be 1¾ inches and at the rim 1½ inches exclusive of the connecting curves at web and rim Six pieces 10½ inches long, 2¾ inches wide, and ¾ inch in thickness, must be carefully fitted as shown in Fig. 174.

After fitting, the connecting joints are glue sized, and when dry carefully scraped smooth with a sharp chisel, and a saw kerf 5/16 inch deep cut in each. The tongues used for tenons in these kerfs should be a little less than ⅝ inch long, the grain of the wood running always at right angles to the line of the joint to give the greatest strength to the tenons.

The six pieces should be glued in two groups of three pieces each; and when dry, these two groups can easily be refitted, if necessary, and glued.

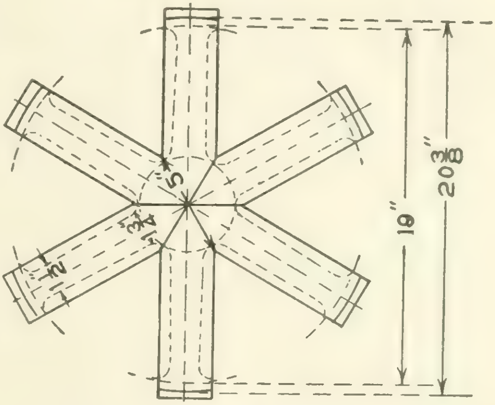


Fig. 174.

The next step is to draw, from the center formed by the intersection of the six pieces, a circle 5 inches in diameter, representing the web of the arms, and, near the extremities of the pieces, the arcs of a circle 20⅜ inches in diameter, representing ¼ inch greater diameter than the outside diameter of the rim. Carefully divide these last arcs into six equal spaces with the dividers, bringing the points thus obtained as nearly to the middle of the six arms as possible; and from the six points thus spaced, draw radial lines connecting them with the center or intersection of the six arms. These radial lines (shown dotted in the drawing) will be the center line of each arm.

Saw off the ends of the arms on the above 20⅜-inch arcs, and from the center again draw on the six arm-pieces a third circle, whose diameter should be at least ⅛ inch less than the inside diameter of the rim, in this case 19 inches. On these arcs measure ¾ inch on each side of the center line, and on the circle representing the web, measure $\frac{3}{8}$ inch on each side; connect these points from web to rim, and the arms will be $1\frac{3}{4}$ inches wide at web, and $1\frac{1}{2}$ inches at the rim.

These lines are shown by the dotted lines in Fig. 174. The width of the ends of the arms passing through the rim should be about $2\frac{1}{2}$ inches, and the sides drawn parallel with the center line of the arm, as shown for hand-wheel arms in Fig. 169. The radius of the circle connecting the sides of the arms and the web, must be such as to be tangent to the edges of the two connected arms, and also tangent to the circle marking the diameter of the web.

The smaller curve connecting the two edges of each arm with the rim must be of such radius as to be tangent to the arm and to the 10-inch arcs which mark the inside of the rim (less $\frac{1}{8}$ inch). All these lines are shown dotted in Fig. 174. The arms are now ready for sawing to shape on the band or scroll saw, care being taken to saw just *outside* of the lines so that each arm may retain its full size and width.

After sawing to shape, the edges must be dressed smooth and free from all irregularities of the sawing.

Next, from the web circle, taper the arms to $\frac{5}{8}$ inch in thickness at the extreme ends, care being taken to see that the taper of both sides of the arms is uniform from the web circle to the rim.

The shape of the arms should be elliptical or nearly so, and a cross-section at any point in an arm may be obtained in the same manner as described for the hand wheel shown in Figs. 170 and 171, and the methods used for shaping and finishing are the same. For building the rim, a wooden chuck $20\frac{1}{2}$ inches in diameter will be necessary.

A board $\frac{7}{8}$ inch in thickness and having a bar 8 inches wide and of the same thickness, well screwed to the back with wood screws will be all that is necessary for a pulley of this size. To the 8-inch bar, the iron face-plate of the lathe is screwed, and the whole turned off true in the lathe, especially the face of the chuck to which the first layer of segments is to be glued.

Strips of heavy paper are often glued between the first layer of segments and the face of the chuck, so that the rim and the chuck may be easily separated when the rim is turned and finished. The paper usually splits, allowing separation without injury to the wood. A better method, however, is to glue twelve blocks, each 2 inches long, 2 inches wide, and ¾ inch in thickness, to the face of the chuck, in the same way as that described for the small hand wheel shown in Fig. 168.

When the rim is finished it may be sawed or cut off through the blocks without injury to the chuck and its future use. The segments to form the rim should be six in number for each layer. They should be ⅞ inch wide, and cut from ⅜-inch or ½-inch stock, lengthwise with the grain of the board, so as to avoid end wood. The first layer is fitted and glued to the blocks (or to the face of the chuck with paper between), and securely clamped with small hand-screws, three to each segment. When the glue is dry, one hour being sufficient for thin ⅜-inch segments, place the chuck in the lathe, and carefully turn off the face of the segments true and straight to receive the second layer.

This layer, in turn, is turned off in the lathe and the third layer is glued on, hand screws being used on each layer as on the first, and the joints of the segments so broken that no two will be directly opposite each other, all joints being carried to right or left of all preceding joints, thus securing the greatest possible strength to the rim.

No nails should be used in any work of this description. Having glued on a sufficient number of layers to form half of the rim, turn it to the required external and internal diameters, making the thin or outer edge of the half rim next to the chuck, and carefully giving the required draft to each side.

Before removing the half rim from the chuck, turn a groove $\frac{1}{16}$ inch to ⅛ inch in depth and of about one third of the width of its thickness in the edge of the rim, as shown in Fig. 173 at *a*. Remove the half rim from the chuck (or cut from the blocks), and proceed to build up and to turn the second half *b* in the same way as the first. Instead, however, of turning a groove on its edge, carefully turn and fit a small projection, or tongue, to the groove in the half *a*, as shown in the drawing. If the work has been done with care and accuracy the groove and tongue will bring the two halves into perfect alignment.

The arms are next fitted centrally to each half of the rim, and the two halves glued together over the arms in the same way as described for the hand-wheel pattern. The projecting ends of the arms are cut off and shaped to form a part of the outside of the rim. The internal curves of the arms at the inside of the rim are also filed and shaped down so as to form true curves without cusps or irregularities. The hub is next glued up in cross-layers as described in Fig. 172, turned out, and glued centrally on each side of the arms.

The pulley being intended for a 1$\frac{3}{4}$-inch shaft, the core prints *x* and *y*, Fig. 173, should be 1$\frac{1}{2}$ inches in diameter, which will give $\frac{1}{8}$ inch of metal for boring out to fit the shaft. The two core prints (Fig. 175) should be turned separate from the hubs, and loosely attached with a pin $\frac{3}{4}$ inch in diameter, and $\frac{3}{4}$ inch long, into each half hub, so that other sizes may be used for larger or smaller shafts. The two half hubs are often made loose so that they may be changed for larger or smaller hubs as may be required for different sizes of shafts. In such cases they are attached centrally to the arms as described for the core prints.

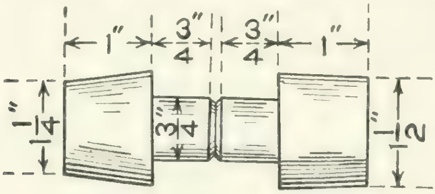
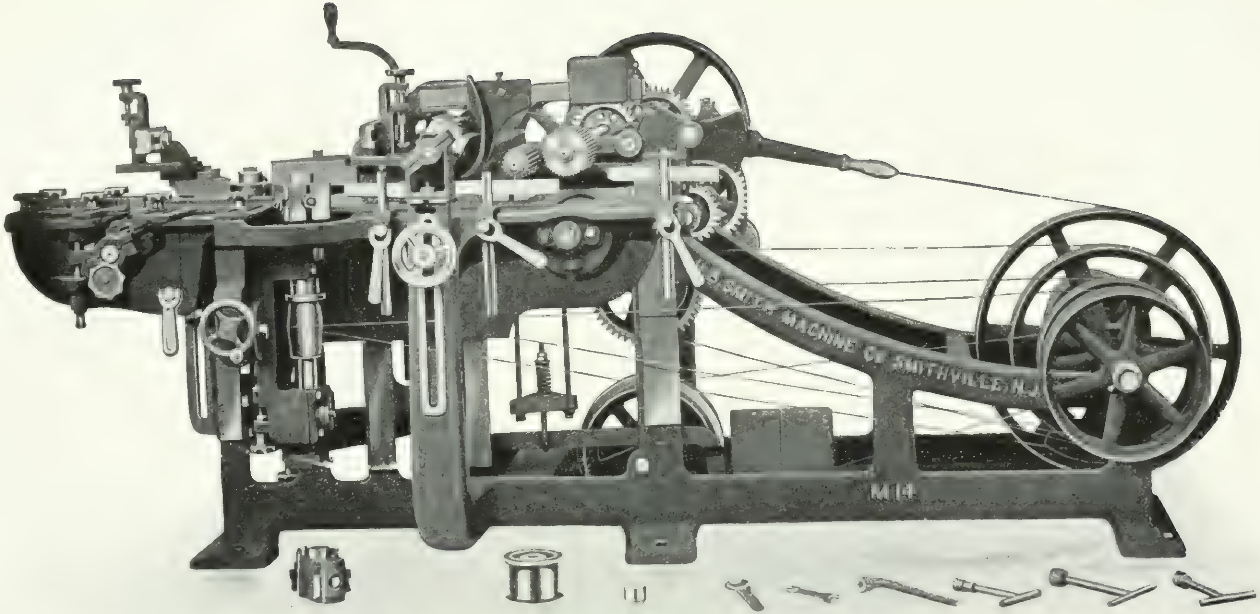


Fig. 175.

A second method in the construction of such special pulleys is as follows:

The half rim having been glued up as described, the *inside only* of this half is turned to the required dimensions and draft, sand-papered, and finished, the width of the half rim being made in this case $\frac{5}{16}$ inch less than the half of the face of the completed pattern. The arms are carefully centered and glued to this half rim; and the intervening spaces between the ends of the arms are filled in with six segments 1$\frac{1}{8}$ inch in thickness, which, when glued and dry, are planed, *not turned*, true and even with the surface of the arms.

A layer of segments of the regular thickness is fitted and glued on over the arms, and layer after layer continued until the full width of the face of the pattern is reached, thus building the arms directly into their place in the pattern as the rim is glued up. In turning and finishing, care must be taken not to strike the arms with the tools while turning out the inside of the outer half of the rim.



6-INCH MOULDING MACHINE.
H. B. Smith Machine Co.

This method will be found convenient for all pulleys of moderate width of face; but as the spaces between the arms cannot be turned out, great inconveniences in reaching these places will be found when the face of the pulley is twelve or more inches in width. These spaces must be dressed out by hand.

The instructions regarding the construction of the last three patterns should be studied carefully, because the general points involved enter largely into the construction of patterns of all kinds, and especially for all work having arms with circular rims.

When pulleys of standard sizes for line shafting are manufactured in quantities, a skeleton pattern consisting of hub, arms, and an independent iron rim is used. This iron rim is of moderate width but may be used for obtaining any width of face desired.

Wooden patterns complete in themselves, as that described for Fig. 173, are used for all special pulleys on machines when the required sizes and widths, as also hubs and connections, are irregular and designed only for the special machine, so that the making of pulley patterns is important in nearly all foundries and pattern shops.

Where the iron rim is to be made, the same care is necessary in the building up of the original wooden pattern. It must be remembered that before the final casting is obtained, two shrinkages will take place: first, the shrinkage of the original casting from which the iron ring is turned, and then the shrinkage of the casting made from this pattern. In addition to this, there must be the allowance for turning the ring both inside and out and for the turning of the outside pulley rim. Suppose the pattern is to be made for a pulley two feet in diameter. The usual allowance for a single shrinkage is made by the shrinkage rule. In this case the allowance must be doubled. Thus in the above pulley, the diameter of the wooden pattern becomes $24\frac{1}{4} + \frac{1}{4} = 24\frac{1}{2}$ inches, standard rule measurements, or $24 + \frac{1}{4} = 24\frac{1}{4}$ inches, shrinkage-rule measurements. As a very smooth surface, free from holes, is required, $\frac{1}{4}$ inch in diameter, or $\frac{1}{8}$ inch all around, must be allowed for outside finish on the iron ring, and $\frac{1}{8}$ inch for finish on the rim of the cast-iron pulley.

The outside diameter of the original wooden pattern is $24\frac{1}{4} + \frac{1}{4} + \frac{1}{8} = 24\frac{5}{8}$ inches, with shrinkage rule. If the final thickness of the pulley rim is to be $\frac{3}{8}$ inch. this, with the allowance of $\frac{1}{8}$ inch for turning out the inside of the iron ring, makes the inside diameter of the wooden pattern 23 inches, and the thickness of the wooden rim $\frac{13}{16}$ inch, all shrinkage-rule measurements.

This wooden-ring pattern must be built up on a chuck, as described for the 20-inch × 6-inch pulley, the segments, six in number for each layer, fitted, glued, and clamped with three hand screws to each segment until a width of $6\frac{1}{2}$ inches is reached.

It is then turned to the above dimensions, *without any draft*, and sent to the foundry, where it may be used for obtaining an iron rim of any required width by first ramming the sand about the pattern, partly drawing it, and then ramming again to a new level.

The casting thus obtained is then turned to the dimensions called for by an ordinary pattern; that is to say, the shrinkage-rule measurements would leave it $23\frac{1}{4}$ inches in diameter on the inside and $24\frac{1}{8}$ inches on the outside, permitting a final finishing of the outside of the rim of the pulley to a diameter of 24 inches. When this is done, two $\frac{3}{8}$-inch holes should be drilled near one edge of the rim and diametrically opposite each other, into which hooks may be inserted for drawing the pattern. This rim should also be turned straight and without any draft.

The arms are usually made with a wooden pattern, which has a dowel-pin hole on each side at the center for attaching the hubs that are loose, the object being to change their length and diameter to suit the width of the rim and the diameter of the shaft upon which the pulley is likely to be placed.

The arms of all pulleys should be straight because of the greater strength given to the pulley as a whole, the driving and resisting power being at least one-third greater than in a pulley of the same dimensions having curved arms. Curved and shaped arms of all kinds are now used only for ornamental purposes and for very light work.

The arms should be six in number, except for very small pulleys, when five and even four are often used. The dimensions of the arms vary greatly, depending on the purpose for which the pulley is to be used, and the weight of the machinery to be driven.

For the beginner the following formula is safe to follow:

$$b = \sqrt[3]{\frac{d \times w}{n \times 8}}, \quad \text{in which}$$

b = the breadth of the arm at the outer end,
d = the outside diameter of the pulley,
w = the width of the rim,
n = the number of arms,

all dimensions being taken in inches. Thus, for a pulley 24 inches in diameter with a rim 6 inches wide and fitted with 5 arms, the formula becomes:

$$b = \sqrt[3]{\frac{24 \times 6}{5 \times 8}} = \sqrt[3]{3.6}$$

Hence, $b = 1.53$ inches or $1\frac{1}{2}$ inches.

The width of the arm should be one-fourth greater at the hub than at the rim. The thickness at the hub and rim should be one-half the width, and the section should be elliptical. The arm just calculated then becomes,

1½ inches wide at rim,
¾ inch thick at rim,
1⅞ inches wide at hub,
1 inch thick at hub.

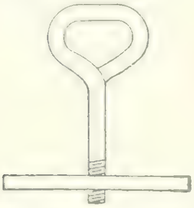
For the skeleton pattern last described, the common method of constructing the pattern for the arms, is to make each arm of a separate piece of wood with the grain running in the general direction of the arm, and to fasten them together at the center with glue and a flat plate or disc, which can also be used as a rapping plate. This pattern need be parted only in the case of very large and heavy wheels. For all ordinary work it can be made in one piece and moulded as directed in connection with the hand wheel, Fig. 167.

HUBS.

An ordinary rule is to make the outside diameter of the hub twice the diameter of the shaft. The two half hubs (one on each side of the arms) are usually loose and are held central by a single dowel pin. Their diameters are adapted to the size of the shaft upon which the pulley is to run, and the length is proportioned to the width of the rim as well as its diameter. The length of the hub should be about two-thirds the width of the rim except in the cases of tight and loose pulleys, where the hub should be a trifle longer than the width of the rim. It may then project about $\frac{1}{8}$ inch on the sides in contact, and $\frac{1}{4}$ inch on the outside.

RAPPING PLATES.

In the description of the making of the pulley pattern, the ring serving as a binder for the hub is spoken of as a rapping plate. When a pattern is imbedded in the sand, the latter is closely compressed all about it, and slightly adheres. The moulder is therefore, in the habit of rapping the pattern gently in order to loosen it in the sand before attempting to draw it. If the pattern is not provided with a metal plate, the moulder will drive the sharp point of a lifter into the wood and strike it alternately on opposite sides and at the same time use it to lift the pattern from the sand. This mars the pattern and will in time ruin it. The rapping plate, shown in the engraving, is a piece of thin metal $\frac{1}{8}$ to $\frac{3}{16}$ inch thick, inserted so that it is flush with the parting face of the pattern and is held by wood screws with countersunk heads. These plates are drilled and tapped for a $\frac{3}{8}$-inch screw and should be the same for all patterns in the foundry so that one set of rods can be used interchangeably. The method of using is to screw the rod into the plate and rap it gently to and fro until the pattern has been loosened, when it may be lifted. For small patterns, one rapping plate will be sufficient and this should be so placed that the hole for the lifting rod comes directly over the center of gravity of the piece. This will prevent tilting of the pattern as it is lifted from the sand. For medium sized patterns, two rapping plates should be provided, so that the pattern can be raised from two opposite sides. For still larger patterns three or four rapping plates are used; the object being to give such perfect control when drawing that there can be no tearing away of the sand.



Rapping Plate.

METAL PATTERNS.

Metal patterns are extensively used where either one of two conditions prevail: first, where the character of the work is so light and delicate that a wooden pattern could not hold together, as in ornamental castings; and second, where such a large number of castings are to be made that the wooden pattern would not last long enough to complete the work. Metal patterns may be made of iron, brass, or aluminum. The latter metal is coming into great favor because of its light weight and its freedom from corrosion by the moist sand. These patterns should be given a light coating of shellac varnish, but it is not absolutely necessary. Where iron is used, some preservative must be put upon the surfaces to protect them from rust. The best method is to warm the metal and rub it with a rag dipped in melted beeswax. This excludes the air and leaves a smooth surface so that it is easily drawn out of the sand. This, however, is not a very durable protection: the more common method is to use a shellac varnish. In order that the varnish may adhere, the metal should first be wet with a solution of sal ammoniac, and, when dry, sand-papered and shellaced.

In the small 12-inch crank pattern shown in Fig. 176, is shown a very simple *one-piece* pattern. In spite of its simplicity it requires considerable skill in shaping and in obtaining the necessary draft. The parting of the mould will be on the line C D. The piece *e*, for the main body of the pattern, should be made rectangular in form, and laid off with center lines from which the positions of the bosses *c*, *b*, and *d*, and the core print *x* may be drawn on the upper and lower sides respectively. The bosses are turned on the lathe to the required form, and given a draft of ¼ inch to 12 inches. After *b* and *c* have been glued on, the part *e* is sawed to shape, sawing close to, but not touching *b* and *c* with the saw. The thin boss *d* is next glued in place, after which *e* is filed and dressed to the required shape and even with *b* and *c*, giving it the same draft, ¼ inch to 12 inches, but in the opposite direction from the parting line C D. The rib *a* is next turned on the lathe, and one side split off on the band saw, after which it is fitted between *b* and *c*. The core prints may be turned with a small tenon on one end to fit into

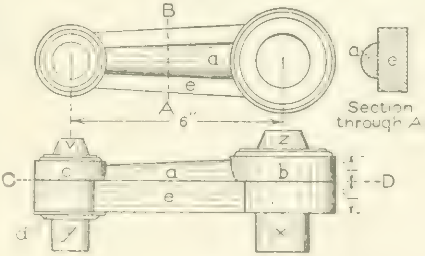


Fig. 176.

holes bored in the pattern, or they may be turned flat on both ends and nailed on. Core prints *x* and *x* must have no more draft than is given to the body of the pattern ($\frac{1}{4}$ inch to 12 inches); but *z* and *z*, which will be moulded in the cope, must be $\frac{1}{4}$ inch less in diameter at the upper end than the diameter at the base.

The heavy engine-crank pattern illustrated by Fig. 177, differs but little in general construction from that shown in Fig. 176, except that, being large and heavy, it must be built up out of thin stock, as shown in the drawing.

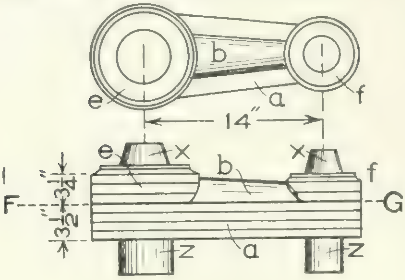


Fig. 177.

The stock is first glued up to the necessary thickness, after which it is laid out and sawed to shape as one piece, the saw table being tilted slightly to give the required draft, which in this case must not be more than $\frac{1}{8}$ inch or $\frac{3}{16}$ inch to 12 inches.

The bosses *e* and *f* are also glued up out of thin stock, the pieces being crossed so that the grain of each will be at right angles to that of the other, as illustrated in Fig. 172, after which they are turned with a draft of $\frac{1}{4}$ inch to 12 inches, and fitted to *a*.

Of the four core prints only *x* and *x* will have excessive draft, as explained in connection with Fig. 176; *z* and *z* must have no more draft than the body of the pattern. The parting of the mould, as in the former case, will be on the line F G.

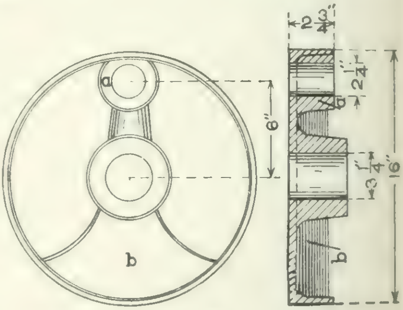


Fig. 178.

In Fig. 178, is illustrated a finished cast-iron *disc crank* for an engine of 12-inch stroke. This crank is finished on the face, on the outer edge, and on the end of the hub. It is bored out $3\frac{1}{4}$ inches to fit on the engine shaft, and $2\frac{1}{4}$ inches to receive the wrist pin. An addition of $\frac{1}{8}$ inch must be allowed on the pattern for finish of the face, and the same on the end of the hub; $\frac{3}{16}$ inch will be sufficient to add for finish on the outer rim, making the diameter of the pattern 16 3/16 inches, and the thickness of the disc 9/16 inch. A sectional view of the pattern is shown in Fig. 179.

The disc for this pattern must be made of two thicknesses of sectors, six in number for each thickness, which, after being fitted, glue-sized, and glued together, are planed off true on both sides, and glued on each other so as to break joints, as shown in Fig. 180. When dry, the disc thus obtained is sawed to a diameter of 16¼ inches and glued to the wooden chuck on the iron face-plate of the lathe with small sectors of thick paper between, or else glued to small blocks on the chuck, from which, after turning, it can be cut as illustrated in Fig. 168. The rim is now built up on the disc out of segments 3/8 inch or ½ inch in thickness, as directed for the 20-inch pulley (Fig. 173), with not less than six segments to each course. The hub is glued up as described, and, after gluing on the disc, the whole is turned to the required size and shape.

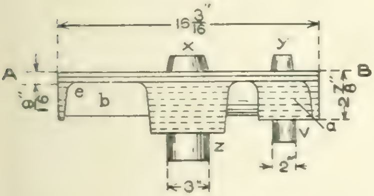


Fig. 179.

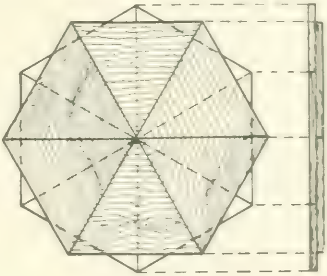


Fig. 180.

In the case of this disc-crank pattern, a small disc of paper (or a block, if blocks are used) should be placed, without gluing, under the center of the disc, to prevent looseness and vibration while being turned in the lathe. The boss *a*, to receive the wrist pin, must be glued up in the same way as the hub (see Fig. 172), and turned on the lathe, after which it is fitted into position as indicated in Figs. 178 and 179. The counter-weight *b* is next shaped from a single piece, or it may be glued up of several thicknesses of ½-inch stock. In sawing this block to shape, the band-saw table should be tilted so as to give it a draft of 3/8 inch to 12 inches. Give the inside of the rim, the hub, and the boss *a*, the same draft, but the outside of the rim should not have a draft of more than ⅛ inch to 12 inches.

When turning on the inside of the rim, a *fillet* or curve must be made where it joins the disc, of ⅜-inch radius, as shown at *e*, Fig. 179. The same curve must be turned at the base of the hub. Around the counter-weight block, and also around the wrist boss, a ⅜-inch leather fillet can be used.

For convenience in moulding, the two core prints *x* and *y* should be turned with a tenon ¾ inch in diameter and ¾ inch long, to fit into the holes in the face of the disc, so that they can be removed when the pattern is laid on its face on the moulding board. The core prints *v* and *z* are turned without tenons, being glued and nailed in position.

FILLETS.

The fillets spoken of in connection with Fig. 179, are used in all except the most simple patterns. They consist of a small quarter curve varying in size from ⅛ inch radius upward, depending on the size of the pattern and the room they can be allowed to occupy. They should be placed in all corners, wherever possible, so that there may be no sudden changes in the direction of the surface of the casting, which causes weakness, the fillets adding greatly to the strength of the casting.

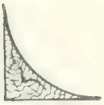
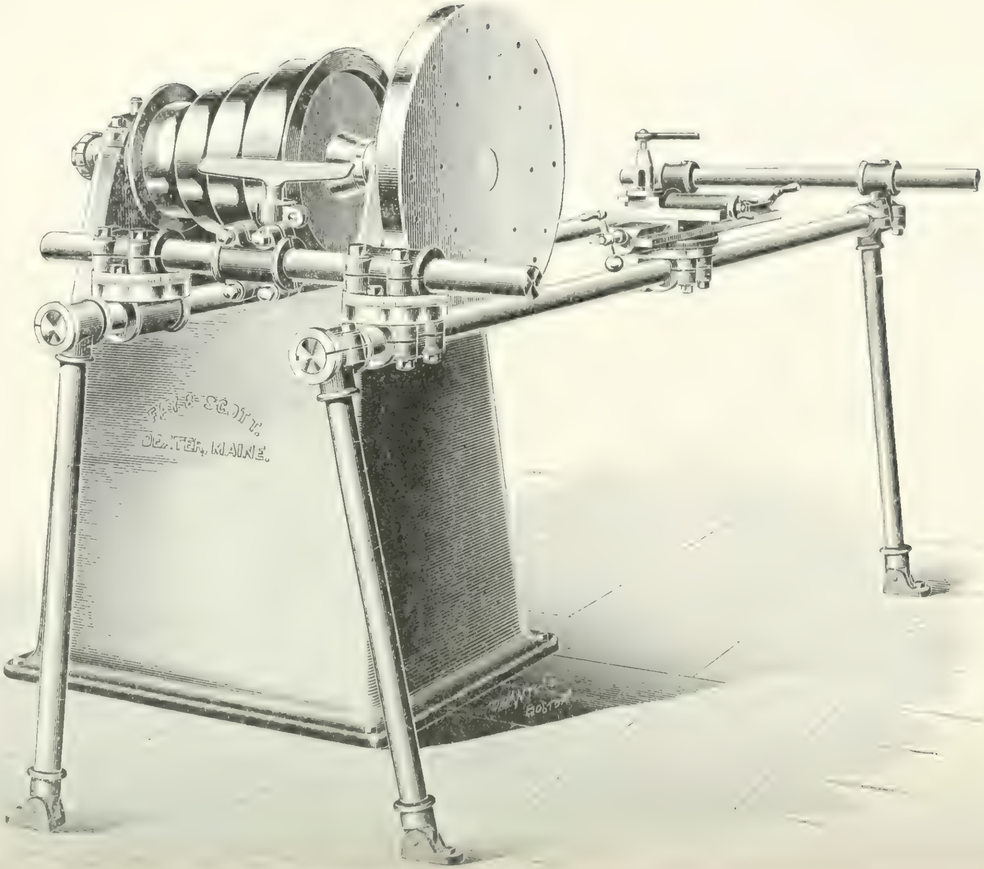


Fig. 181.

These fillets are made in various ways, the wooden fillet, cut as in Fig. 181, being commonly used for all long, straight angles, or for very flat curves to which it can be bent.

For irregular angles and for short radius curves, beeswax was formerly used, but the modern *leather fillet* has almost entirely superseded beeswax and other material for this purpose. It is easily applied, shaping and adapting itself to any and all positions and angles. It can be bought in all sizes from ⅛ inch up, the sizes running by sixteenths. The method of applying it is to cut it to the necessary length and lay it on a board where the glue can be easily brushed over it. It is then laid in the angle and rubbed into position by means of a dowel rod, the end of which must be rounded off as shown for the connecting dowel pins of a parted pattern, Fig. 152. The dowel rod must be of such size as to impart the required curve to the soft, pliable leather fillet. As soon as the fillet is rubbed into position all surplus glue must immediately be wiped off before it sets. This is easily done with a small piece of waste

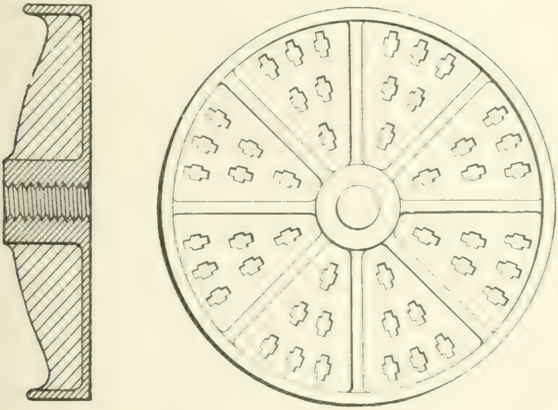

SCOTT,
DEXTER, MAINE.
BOSTON

or a rag dipped in the hot water of the outer glue-pot and wrung out nearly dry, care being taken not to wet any part of the pattern more than can possibly be helped, after which it must at once be wiped dry.

These leather fillets will be found more pliable and more easily placed and rubbed into position if the glue used is first allowed to cool slightly. Very hot glue stiffens and crinkles the leather, causing it to work hard.

FACE PLATE.

It is sometimes advisable to use cores even if it is quite possible to construct the pattern so that it would core its own holes. This is the case where it is desired that the faces of the casting and the holes shall be smooth and as true as possible without expensive machine work. The finished face-plate of an engine lathe illustrated in Fig. 182 is a good example of such work.


a. Fig. 182. *b.*

It will be readily seen that the pattern for this casting could be put in the sand and withdrawn from the mould, leaving the sand standing where the holes are located.

The trouble that arises from this method is due to the fact that when the metal is poured and allowed to flow about the fragile projections that are left to form the holes, the sand washes away, so that the holes in the casting are irregular and much smaller than those in the pattern. For these reasons the holes should be cored, as the core sand is firm and better able to resist the washing action of the flowing metal.

The patterns for such a face plate, a cross-section of which is shown in Fig. 183, should be made as follows: The allowance for finish on the face of the casting should be not less than $\frac{3}{16}$ inch, and the same should be added to the diameter and also to the end of the hub. Having thus determined the thickness and size of the pattern, the disc should be built up of from four to sixteen sectors, according to the size of the plate. If the diameter is between 24 and 42 inches, sixteen sectors should be cut out, each filling an arc of 45°, so that when eight are placed edge to edge they will complete the circle. The thickness should be a little more than one-half the completed thickness of the pattern disc, and they should be laid up so as to form two layers, breaking joints with each other as shown in Fig. 180. When the disc is formed, the hub should be first glued in position, this also being built up of pieces glued together, and the whole attached to a large wooden chuck and iron face-plate of the pattern lathe in the same manner as described for the disc-crank (Fig. 178). The rim is next built upon the disc in the same way as has been described for former patterns. If the face plate is very large, the segments may be $\frac{1}{2}$ inch or even $\frac{5}{8}$ inch in thickness, and to avoid end wood, eight, twelve, or even sixteen, segments may be used for each layer according to the diameter of the rim.

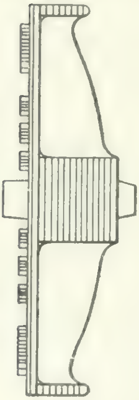


Fig. 183.

The pattern now consists of the disc with the rim and hub in position, but larger than they should be. It is, therefore, placed in the lathe and carefully turned over its whole surface, each part and thickness being brought to the shape and dimensions of the completed pattern, care being taken to turn in a fillet of $\frac{1}{4}$ inch to $\frac{1}{2}$ inch radius, depending on the size of the required casting, in the angles connecting the rim and the hub with the disc. Next put in the ribs; it is not necessary to form these out of built-up material, for each may be cut from a single piece. They should be carefully fitted to form a close joint with the rim, the disc, and the hub, before they are glued in position. When this is done, all angles formed by the rim, ribs and hub with each other should be carefully filleted.

After the fillets are in position, it remains to provide for the coring of the holes. This is done by first laying out upon the face of the pattern the location and size of the holes. It is upon the points thus located that the core prints are placed. Before this is done it must be decided which side of the casting is to be made uppermost.

Where a large, flat surface is to be given a finish, it is desirable that the metal should be as clean and free from sand and blowholes as possible. As the iron has a greater specific gravity than the sand of the mould, all particles of sand that may be washed away and all gases generated, rise to the surface of the molten metal. Those imprisoned by the cooling of the iron form the dirt and blowholes that disfigure the completed casting. In a casting such as the face-plate under consideration, it is desirable, then, that the face should be upon the lower side when the metal is poured. For the sake of convenience in setting the cores, the prints are put upon the face and make their impress in the sand of the drag. They should be glued and nailed in position after the pattern itself has been sand-papered. The core prints for the hole through the center are also put on in the same way.

PIPE CONNECTIONS.

Many patterns which at first may seem to be quite formidable, will, after a little study, resolve themselves into a few very simple parts, nearly all the work for which may be done in the lathe. Of this the tee pipe connection shown in Fig. 184, is a good illustration.

A sectional view of the casting, threaded and having a pipe screwed into the right-hand end, is shown in Fig. 185.

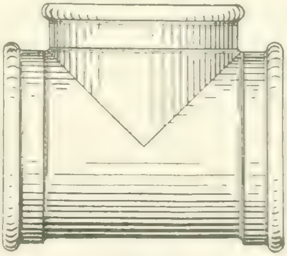


Fig. 184.

The completed pattern for this casting is illustrated in Fig 186, with its core prints *a*, *a* and *a*, and must be parted as shown in Fig. 187. The entire pattern may be made at a single turning as illustrated in Fig. 188. The preparation of the wood for this pattern is similar to that described for the pattern of the brass bearing, Fig. 150; the two halves having the necessary dowel pins inserted, and glued together at the extreme ends only.

When there is not time for the glue to dry, all such *parted* work may be held together while being turned, by having staples driven into the ends as shown in Fig. 188. Indeed, for all large and heavy work this method is to be preferred; two, and even four, staples being used in each end as the size of the work may demand. When the turning is completed, it is only necessary to cut a V-shaped opening into the two halves of *e*, into which the part *f* is fitted and glued. When the glue has set and is sufficiently dry, the joint may be further strengthened by nailing, or by inserting and screwing a thin metal connecting plate flush with the parting side of each half of the pattern. This, however, will be necessary only when patterns are large and heavy, or when unusual strength is required.

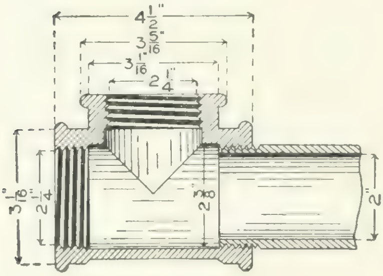


Fig. 185.

The core box for this pattern, as will be seen in Fig. 189, is the usual half box and is made by working out the box in one piece, long enough to make the two parts *a* and *b*. The two parts are united by cutting a V-shaped opening in the part *a* and fitting *b* into it in the same way as described for the pattern. The whole is then glued and screwed to the board *c*, and the two triangular blocks *d* and *d* are glued in the angles to add strength to the completed box. In case the pattern is for a very small pipe, 1½ inches or under, the part *b* may be abutted against the side of *a*, as shown by the dotted line, and the side of *a*

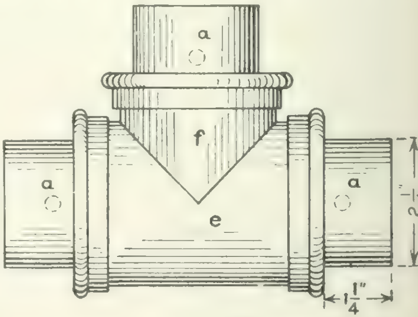


Fig. 186.

at *e* cut away to the same curve as *b*, giving the same results as in the former method.

The pattern for the 2-inch elbow, Fig. 190, is another illustration of how such work may be simplified, and time saved, by doing the greater part of the work in the lathe.

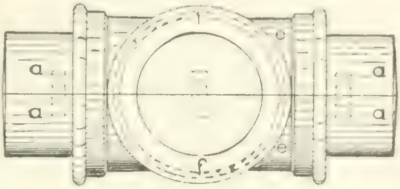


Fig. 187.

As these elbows are usually cast in large numbers, the pattern should be made double as shown in Fig. 191. To construct the double pattern, a ring is first turned like Fig. 192, a cross-section of which is a semicircle as shown in the lower right-hand corner of the drawing. This ring is cut into quarters, and the four pieces *e*, *e*, *e* and *e* make the quarter turns for the two halves of the double pattern.

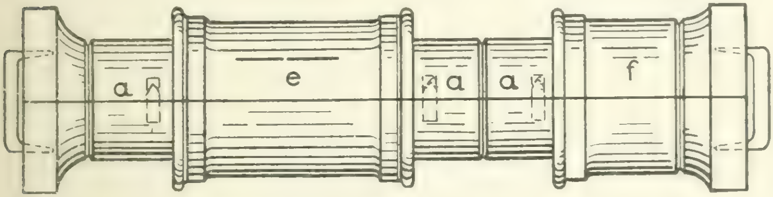


Fig. 188.

The ends, including the core prints and connecting tenons, are turned in one piece as shown in Fig. 193, the stock for which is prepared, with the inserted dowel pins all in position in the same manner as described for the tee pattern, Fig. 188. The quarters, *e*, *e*,

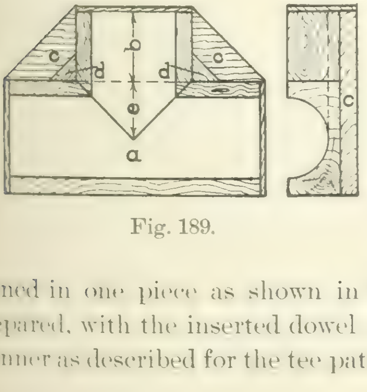


Fig. 189.

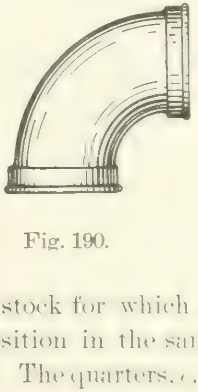


Fig. 190.

e and *e* are clamped together two and two, and the ends carefully bored to receive the tenons which are then glued in position and further strengthened by a wood screw as shown in Fig. 191.

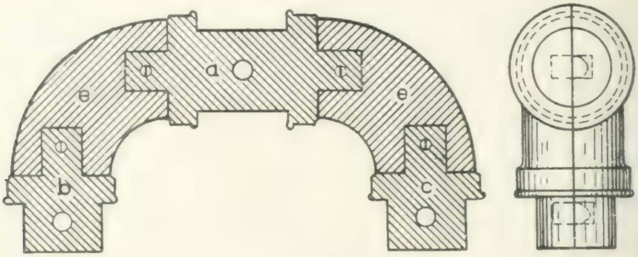


Fig. 191.

In Fig. 194, the core box for this double pattern is shown, and as will be seen the most difficult part of the work can be done in the lathe. Fig. 195 shows two pieces jointed and clamped together which must be screwed to the face-plate of the lathe and turned out to make the two corners *c* and *c*. The three straight parts *d*, *d* and *d* are worked out in one long piece and afterwards cut to the required lengths, after which the five pieces are glued and screwed to the board *a*. The ends *e*, *e* are next put on and the required half core box is complete.

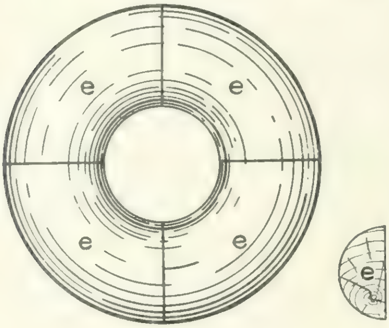


Fig. 192.

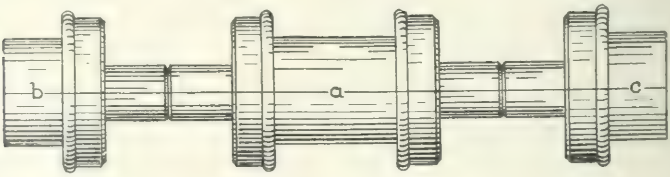
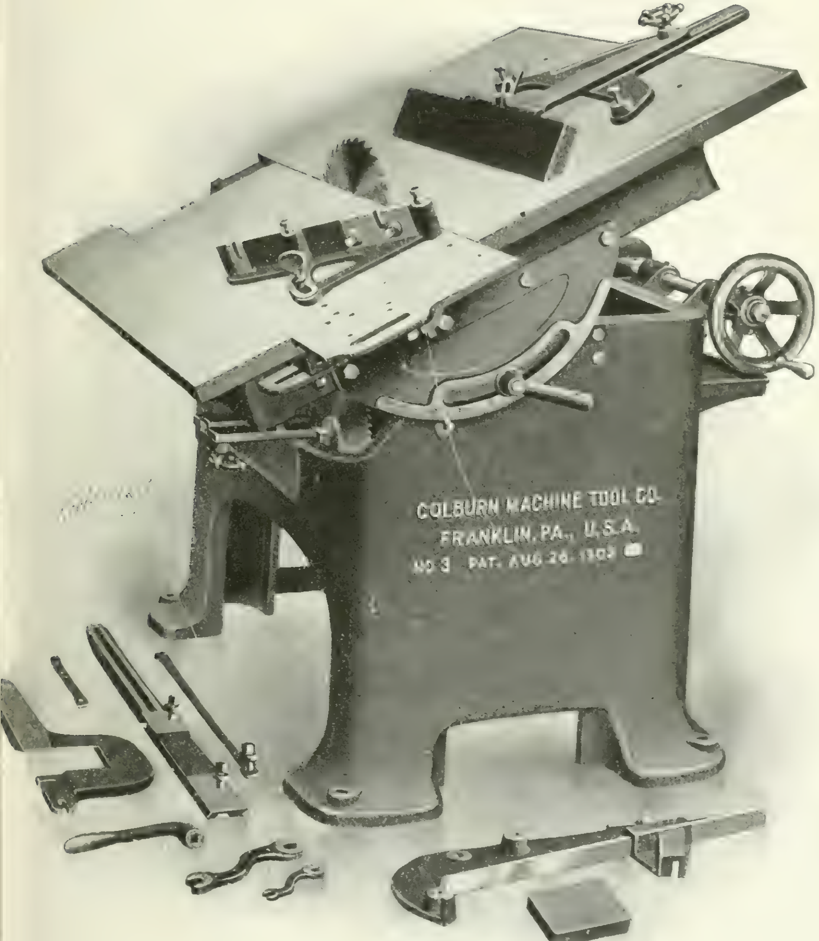


Fig. 193.

Another reason why the pattern for pipe elbows should be made double is that otherwise the core prints would require to be made of great length in order to balance, sustain, and keep the heavy core



UNIVERSAL SAW TABLE.
Coburn Machine Tool Co.

in position: the tendency being to sag in the middle, or float on the molten iron, and thus make the upper side of the casting too thin, all of which is avoided in the double pattern.

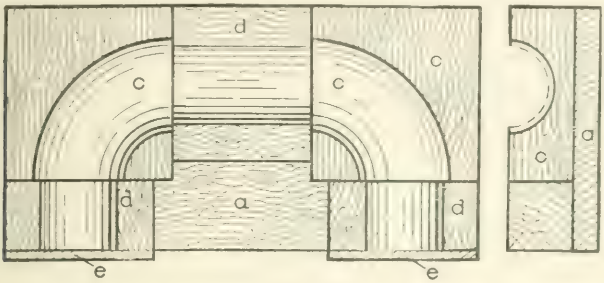


Fig. 194.

A pattern for the return bend, Fig. 196, can be built up and constructed in the same manner as described for the elbow; the semicircular returns, not only for the pattern, but also for the core box, being turned in the lathe, together with the ends and core prints for the pattern. As there will be no middle support for the core in this case, the core prints must be made, as shown in the half pattern, Fig. 197, of sufficient length to balance the heavy semicircular core, and also to keep it in its true position in the mould.

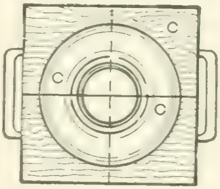


Fig. 195.

The small wood lathe chuck, a vertical section of which is shown in Fig. 198, will serve as a simple illustration of the long

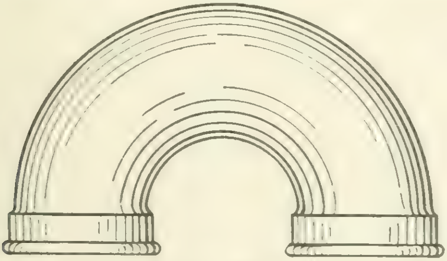


Fig. 196.

core print and *balanced* core. The casting must be counter cored: that is, the cored opening must be enlarged at the forward end, adding to the size and weight of that end of the core, which, as will be seen, has no support except that afforded by the extra length of the core at the opposite end. The pattern for this chuck is shown in Fig. 199, and the core print must have a length at least twice as great as the depth of the hole in the chuck. The core box is shown in Fig. 200.

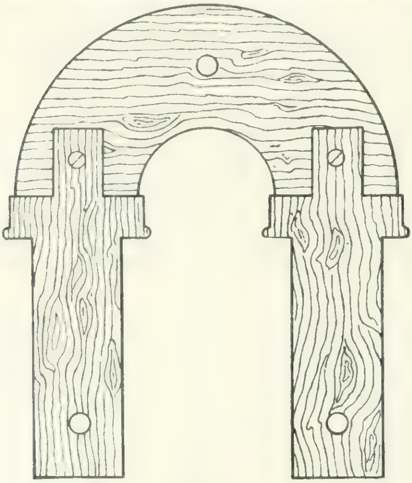


Fig. 197.

When pipes or cylinders are of moderate size with deep flanges for bolting together (Fig. 201), the flanges for the pattern are turned out of a separate disc as shown in Fig. 202, and firmly glued and nailed on over the core prints and against the ends of the main body of the pattern; the core print being made of sufficient length to receive the flange. A recess is sometimes turned in the inside end of the core print to receive the inner edge of the flange as shown in Fig. 203, and into which it is fitted, thus adding greatly to the strength of the joint.

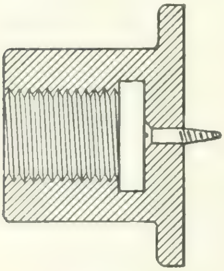


Fig. 198.

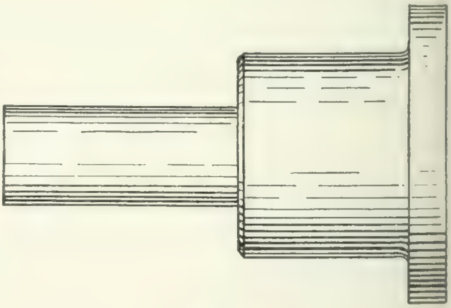


Fig. 199.

The flanges should be made by gluing up *three* pieces and crossing the grain of the pieces so that the grain of each will run at right angles to that of the other. In gluing pieces together for thin discs, *three* pieces should always be used. *Two* thin pieces glued together will always warp.

A still better and stronger method of making large flanges is to cut out segments, five or six for each course, and fit and glue up on a chuck and face-plate in the same way as described for the hand wheel rim (Fig. 168); two or three courses being used for each flange, which after being turned to the required size and form, the ring is sawed in two with a very thin saw, and each half fitted into place on the pattern. The main body of the pattern is glued up out of strips as shown at *a*, Fig. 201, and for turning, the two halves are held together by means of staples as shown in Fig. 188.

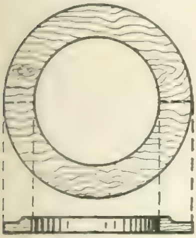


Fig. 202.

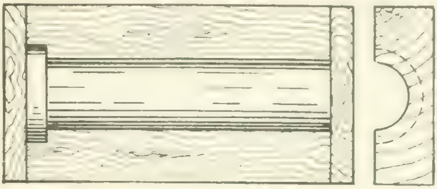


Fig. 200.

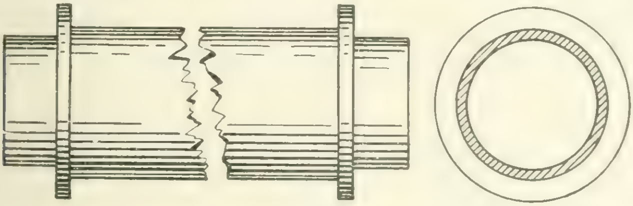


Fig. 201.

A short temporary block is then fitted and glued into the opening in each end to receive the lathe centers. A staple plate, similar to that illustrated in Fig. 205, may be used to great advantage for all work of this kind, making as it does, a secure connec-

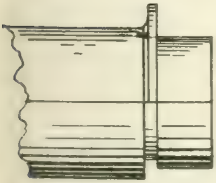


Fig. 103.

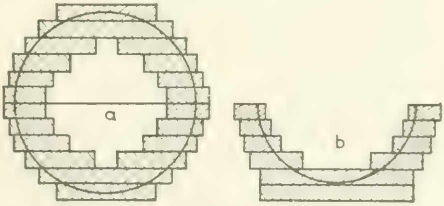


Fig. 204.

tion and doing away with the otherwise temporary center block.

The method of constructing the core box for this or similar patterns, is shown at *b*, Fig. 204.

Tees, elbows, and other bends and connections, when large, are built up in a similar way, thus making a lighter, and also more durable pattern.

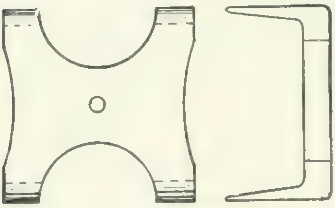


Fig. 205.

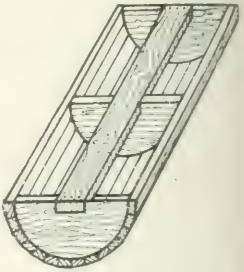


Fig. 206.

For large cylinders, a much lighter and simpler method of constructing the pattern is shown in Fig. 206. For each half of the pattern the two end discs, and the middle semicircular disc are connected together by a strong center bar, which is fitted, glued and screwed into each, serving not only to strengthen the pattern, but also to hold the connecting dowel pins. When the two halves of the pattern are clamped together (with staples) it serves also as a secure means of centering in the lathe.

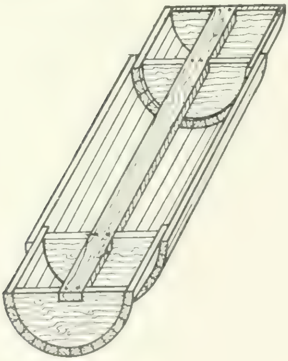


Fig. 207.

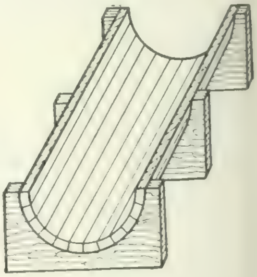


Fig. 208.

The staves forming the body of the cylinder are fitted and glued to each other and screwed, or nailed to the discs After the cylinder has been turned, the core prints and flanges are built up and turned separately, and glued and screwed to the ends of the cylinder from the inside of the end discs.

Fig. 207 illustrates still another and better method of building up the cylinder and core prints in one piece and completing the whole at a single turning. The core prints, as shown, are staved up first, and then the staves to form the body of the pattern are fitted, glued and screwed, or nailed, over the ends of those which form the core prints. Should the body of the cylinder be long, one, two, or more middle semicircular discs must be used.

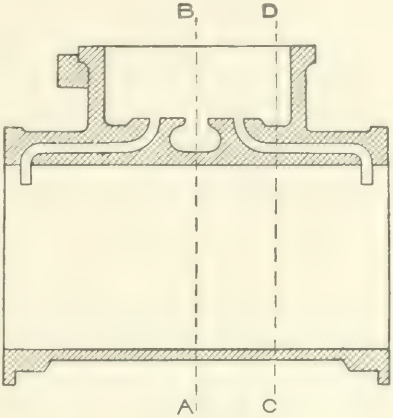


Fig. 209.

A similar construction for the core box is shown in Fig. 208, and is to be preferred to all others because if laid out and built to the exact size, the labor required to reduce the staves to a perfect semicircle of the required radius is very little.

ENGINE CYLINDER.

The slide-valve engine is built in a great variety of forms. Fig. 209 represents a sectional view of the cylinder of a very common type. At *e* Fig. 210, we have a cross-section through the steam chest and exhaust port at *A B;* and at F, a cross section at *C D* through the steam port.

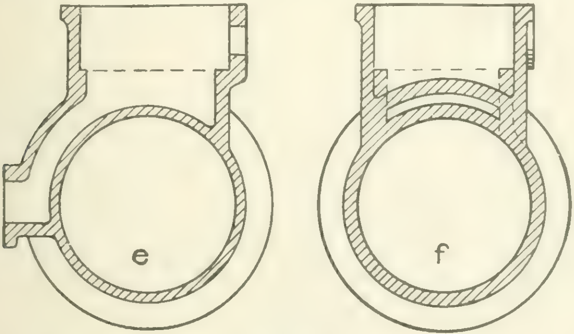


Fig. 210.

When the cylinder is small (ten inches or under in diameter) the pattern is usually built up solid, but if more than ten or twelve inches in diameter it should be built of staves, as shown in Fig. 211.

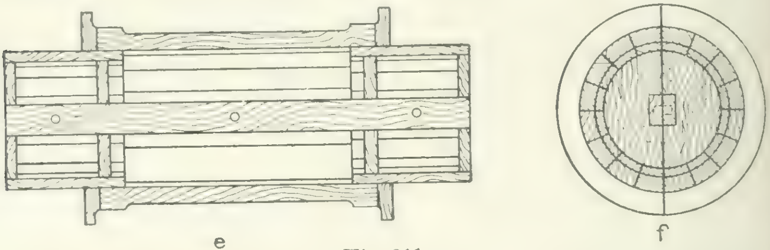


Fig. 211.

When the size is thirty inches or over, a loam mould is usually made as will be fully described in the section on Foundry Work. The size limit, however, varies greatly in different foundries. The construction of the pattern is illustrated in Fig. 211, and needs no description here, it being the same as already given for Fig. 207. The flanges, however, should be built up of segments of two or three layers each as shown in Fig. 212. After gluing up to the necessary thickness to make the flange, it is sawed in two halves, jointed and carefully centered on a wooden chuck and turned to the dimensions required.

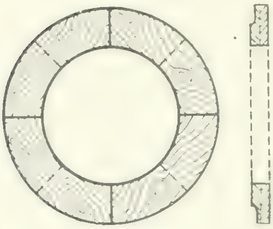


Fig. 212.

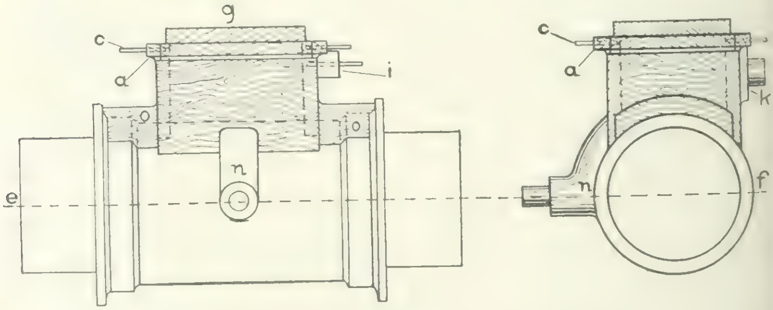


Fig. 213.

The centering must be done with accuracy, or one half of the flange ring will be larger than the other. The steam chest is next built and fitted centrally on the upper half of the cylinder pattern as in Fig. 213. The projections *a*, *a*, which give the extra width of metal for the bolts of the chest cover are left loose, being kept in place by long wires or dowel pins as shown at *c*, *c*, so that they

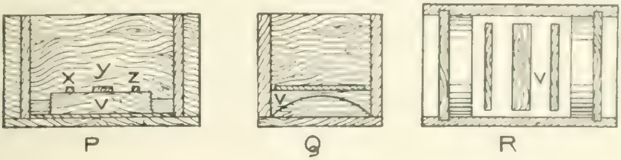


Fig. 214.

can be withdrawn separately from the mould after the main part of the pattern has been taken from the sand. These four strips should be recessed into the corners of the chest one quarter inch, as shown by the dotted lines, to prevent them from being rammed out of place after the dowel pins are taken out. The boss *i* for the valve-rod stuffing box, and also the boss *k* around the steam-pipe opening, must be loose so as to be taken out of the mould after the pattern has been removed.

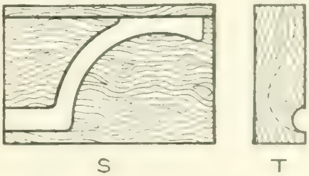


Fig. 215.

The pieces *o*, *o*, at each end of the steam chest, which form a thickness of metal over the steam ports, are next fitted in place, as also the exhaust passage *n* which must be parted on the line of parting of the two halves of the cylinder pattern.

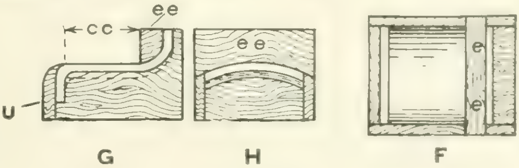


Fig. 216.

The main core box for the cylinder is made in the same way as has been already described for Fig. 208. The steam-chest core box is shown in Fig. 214, in which P is a side view, one side of the box being removed to show the valve seat *v*, and the core prints *x*, *z*, and *y*, which form recesses in the core, into which the upper ends of the two steam inlet cores, and the central exhaust passage core are placed. Q is an end view of the box with one end removed, and R is a view looking into the box from above.

For the core forming the exhaust passage, two half core boxes, one right and one left, will be necessary. One half of this box is illustrated at S, Fig. 215, as also a sectional view at T. The dotted lines show the manner in which the passage is widened to retain the full size of the opening throughout.

Only one core box will be needed for the two steam ports. Three views of the box are given in Fig. 216. At G one side is removed, giving a side view of the construction of the box. H shows a cross section through G with the end *a* removed, and F is a view from above. The core is swept off on the upper side for the length of *c c*, and the bar *c c* as well as the end *a* must be movable so that the core can be taken from the box. Both ends of the core change from circular into straight parts just at the entering of the cylinder, and at the entering of the steam chest.

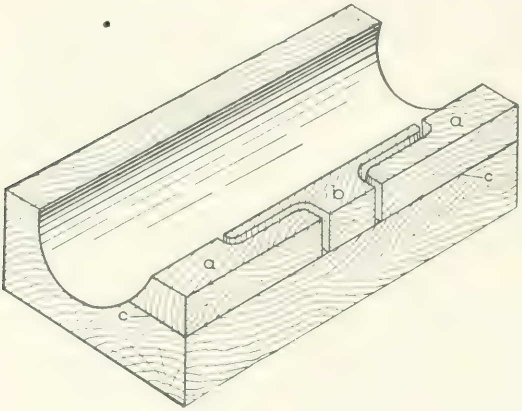


Fig. 217.

The entire set of patterns are simple and easy of construction, if carefully made drawings are furnished to work from; the time and labor required, depending entirely upon the size of the cylinder.

In some slide-valve cylinders, the steam chest is cast separate and bolted to the cylinder, thus affording free access to the valve seat *c*, and a better opportunity for finishing and fitting. In this case the main cylinder core and the two steam inlet cores are made together in the same box, as illustrated in Fig. 217, in which one side of the core box is cut away to a depth of one half of the length of the steam port openings, or to the line *c*, *c*, which must be just one half of the inside width of the box as shown at *H* and at F, Fig. 216.

The part which has been cut away is replaced by the three blocks *a*, *a* and *b*, which are shaped to give the required size and form to the steam-port cores.

These blocks are fastened by dowels, loosely, to the main part of the core box, and after the core has been rammed up, the whole box and core is turned over on its face and the main part of the box is lifted off, after which the two loose blocks *a* and *a* can be drawn away endwise and the block *b* can also be lifted out with ease.

GLOBE VALVE.

The globe valve, shown in section in Fig. 218, is a good illustration of a pattern in which, while the outside may be very simple, the inside is intricate and requires considerable practice and skill to so contruct the core boxes that the core can be withdrawn from them, and at the same time give uniform thickness and strength to all parts of the shell and to the internal partitions.

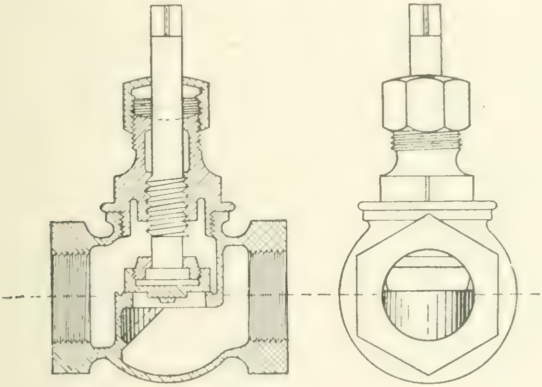


Fig. 218.

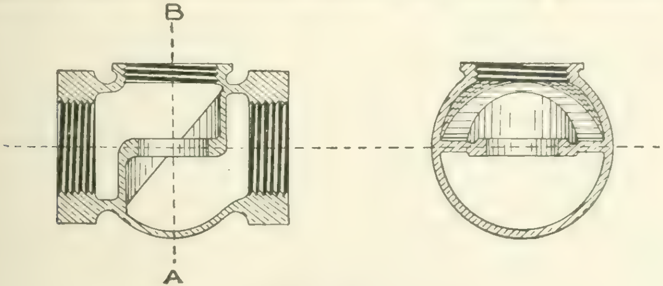


Fig. 219.

In Fig. 219 is shown a sectional view of the body of the valve, and in Fig. 220 an illustration of the completed pattern, from which it will be seen that almost the entire work, with the exception of fitting, placing the dowel pins, and forming the two hexagonal ends, is done in the lathe. The construction is shown in the sectional illustration of the half-pattern, Fig. 221. The wood for the two halves must be of sufficient length to allow for gluing at each end or for the insertion of iron staples. In turning, the greatest care must be taken to center exactly on the parting line of the two halves.

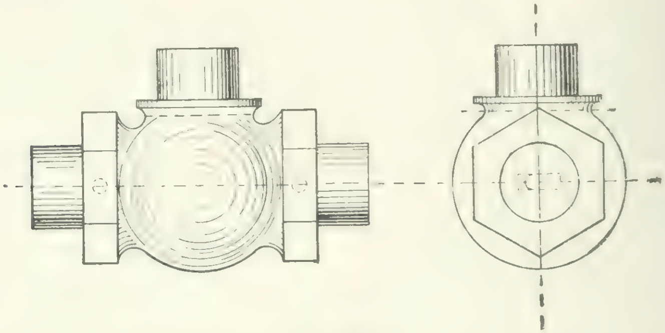


Fig. 220.

A carefully shaped template, such as is shown at *a*, Fig. 221. must be used in turning. This template may be made of a thin piece of wood, but for all purposes for which templates are required in pattern making, and their use is necessarily very great, sheet zinc is the best material. It is soft, and easily cut and filed, and does not dull the cutting tools so much as other metals

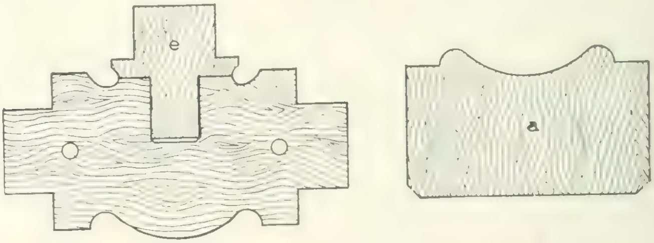


Fig. 221.

Before marking out the template, that the lines may be more readily seen, it should be cleaned with a piece of emery cloth and have a dark coating of the following solution. Dissolve an ounce of sulphate of copper in about four ounces of water and to this add one teaspoonful of nitric acid. Treat the surface of the zinc with this solution, rubbing on with a piece of waste. A thin coating of copper will thus be given to the zinc (also to steel or iron). When applied to finished surfaces they should be rubbed dry, as iron or steel will be rusted.

When the curves of the template will allow of sawing, the zinc template is easily shaped by placing a piece of zinc of the necessary size between two boards, and nailing them together. The required shape having been drawn on the upper board, the whole may be sawed to the form required on the band saw or scroll saw, but preferably on the latter, with a fine tooth narrow saw blade which will give a smoother edge to the zinc. If the boards are firm, the metal will offer no resistance whatever to the saw, nor will the saw be perceptibly dulled. For small curves, lay the zinc on a piece of hard board, and with a pair of sharp pointed dividers the zinc can be scratched half way through its thickness, then by turning it over and placing the dividers in the same center, the other side may be cut in the same way, or so nearly through that it will break off. This affords a truer and more uniform curve than can be obtained in any other way. The legs of the dividers must be stiff and firm so as to be entirely free from vibration. After cutting, the sharp edges of the zinc may be dressed with a fine double-cut file, or better with fine emery cloth or sand paper rolled over a wooden holder.

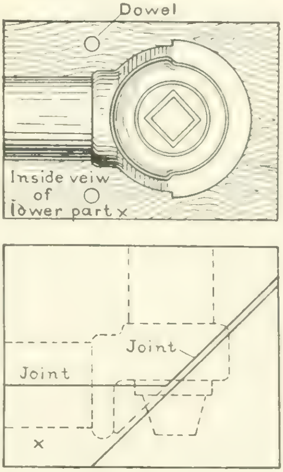


Fig. 222.

The lathe should always be stopped when testing the work with the template, and great care must be taken to make the two ends of the pattern symmetrical.

When the turning is nearly completed the template itself may be tested by reversing the ends. If not true it should be filed to the proper shape as shown by the drawing.

The branch *e* must be turned in the same way as described for the main part of the pattern which is pared off, or planed off in a large pattern, to the exact size of the base of the branch, and when the pattern is large and heavy, one or two wood screws should be used in the tenon of the branch to assist in keeping it in place.

In all small and moderate-sized valves, the flanges are hexagonal in shape as shown in Figs. 218 and 220. The core for a globe valve is made in two parts, and the core box for each part must be made in upper and lower half, making four parts to the

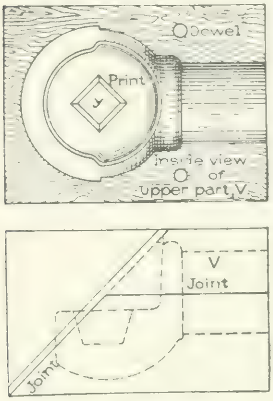


Fig. 223.

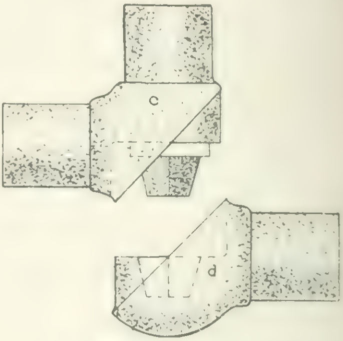


Fig. 224.

core box. This is necessary in order to allow for the removal of the core from the boxes. The internal shape of the boxes are difficult to illustrate on paper, but if the drawings given in Figs. 222 and 223 are carefully studied in connection with the sectional views of the valve shown in Fig. 219 their shape and construction should be readily understood.

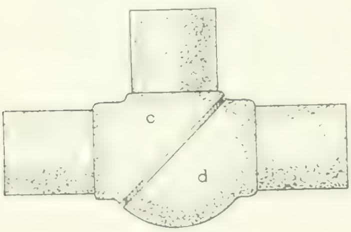


Fig. 225.

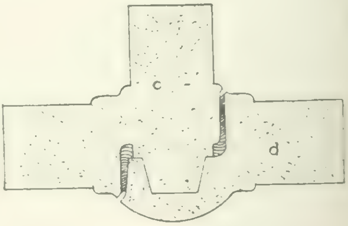
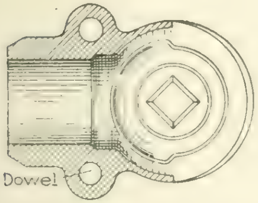


Fig. 226.

Three additional illustrations of the core as made in these boxes are shown in Figs. 224, 225 and 226.

In Fig. 222 there are two views of the box in which the upper part C of the core shown in Fig. 224 is made. This box separates along the two lines marked "Joint" (Fig. 222) and, as will be readily seen, allows the core to be easily removed when the box is opened. The lower part *d*, Fig. 224, of the core is made in the box shown in Fig. 223. The part *e* has a square tenon which fits into the mortise in the part *d*. This mortise is made in the core by means of the print marked Y in Fig. 223, and as will be seen by Fig. 224, this core tenon and mortise will bring the two parts of the core into perfect alignment when they are pasted together.

In Fig. 225, we have an outside view of the completed core and in Fig. 226 a sectional view through the middle of the core, lengthwise; from which the necessity for the tenon and mortise connection will be readily understood, this being the only connection between the two parts of the core. In working out the core boxes it is well to use templates which can be formed and made from the drawings furnished. The templates will aid in getting the proper shapes, and leaving a uniform amount of metal in all parts of the case.



Inside view lower part X

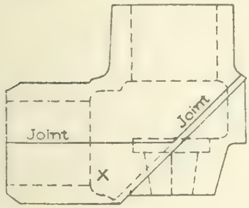
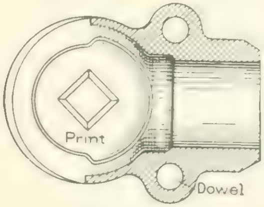


Fig. 227.



Inside view of
upper part, V.

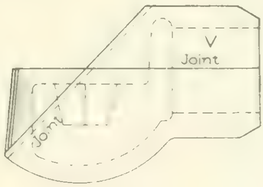


Fig. 228.

Figs. 222 and 223 illustrate the common wooden core box, but to insure uniformity, and because of the necessary wear and fragile character of wood for boxes of this kind, these core boxes should be made of metal. The wooden pattern for the metal core-box must then have an allowance for double shrinkage, and to avoid excessive weight, the box is made in the form shown in Figs. 227 and 228. In this form all unnecessary metal is removed and the connecting iron dowel pins are placed in lugs or thin outside projections as indicated.

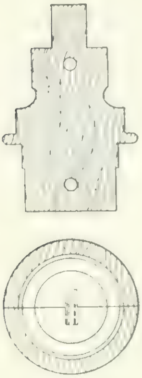


Fig. 229.

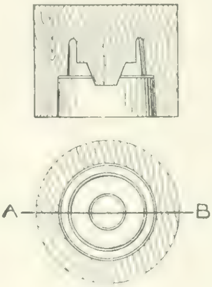


Fig. 230.

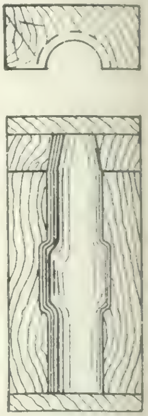


Fig. 231.

Fig. 229 illustrates the pattern for the stuffing box and bonnet of the valve, with core print turned on each end, which, like the main pattern of the valve must be parted, or made in two halves. Two core boxes are necessary to make the core for this part of the valve.

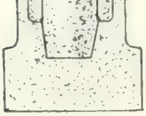


Fig. 232.

From Fig. 230 it will be seen that the core box for the lower end of the core can be turned out on the lathe by using a template of the required shape. For the upper part or stem, the half box shown in Fig. 231, is all that is necessary. By examining the two core boxes, Figs. 230 and 231, it will be seen that here again we have recourse to the tenon and socket form of construction for uniting the two parts of the core which are shown pasted together in the completed core, Fig. 232. The nut for the bonnet is shown in Fig. 233, and the pattern, which is hexagonal, should be so made as to form its own core, as indicated by the dotted lines in the drawing. Fig. 234 shows the pattern for the valve and also the pattern for the valve nut, each of which will form its own core, and Fig. 235 is an illustration of the pattern for the valve spindle.

GEAR WHEEL PATTERNS.

In this special class of pattern work, the greatest accuracy and care must be taken, not only in building up the rim of the wheel, but in fitting and placing on the rim the blocks, out of which the teeth are to be formed, and most of all in laying out the teeth regularly and accurately on the tooth blocks. A pattern for a gear wheel, whose teeth are carelessly made is almost worthless, the time lost in chipping and filing, for the purpose of correction, being too great to allow the use of such a pattern.

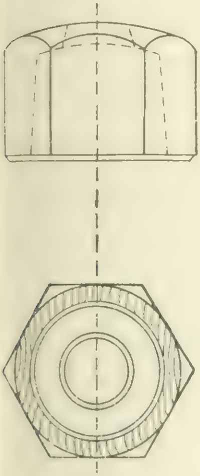
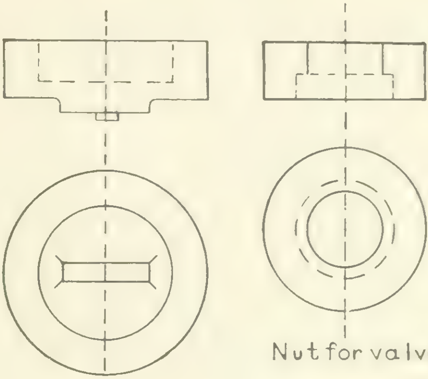


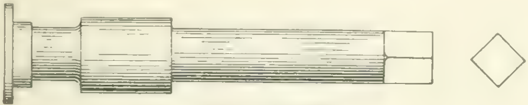
Fig. 233.



Valve

Nut for valve

Fig. 234.



Valve Spindle

Fig. 235.

To insure greater accuracy and smoother running gears, it is now the custom in many shops to have the wooden pattern made in the form of a blank, (without teeth) from which a metal pattern is cast.

This cast pattern is turned up and placed in the milling machine where the teeth are cut and spaced with accuracy and to the exact form of tooth required. This metal pattern is used without *draft*.

This method of making gear patterns, however, is expensive, and is used only when many wheels are to be cast of the same size and number of teeth from the same pattern, and, as in the case of pulleys, the wooden pattern is still used for all special sizes of gears.

For these wooden patterns we shall now give a few hints as to the best methods of construction. As the form of the tooth used by the draftsman will play no part in the construction of the pattern, we think it would be out of place here to enter into a discussion of the relative merits of the single curve, double curve, or other form of tooth.

The single curve or involute tooth, however, has the great advantage of being the only form of gear which can be run at varying distances of axes, and transmit an unvarying velocity and amount of power. The common contention that two gears will crowd harder on their bearings when the single curve, or involute form is used, has not been proven in actual practice. The practical methods for obtaining the curves for either the involute or for the epicycloidal tooth, the two forms in most common use, are taken up in Mechanical Drawing.

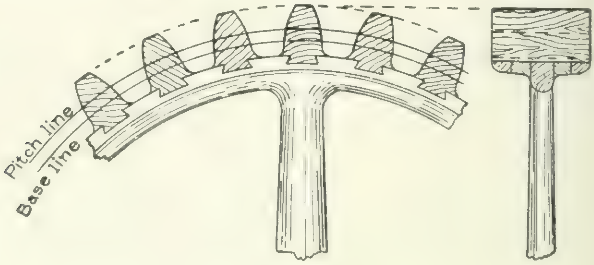
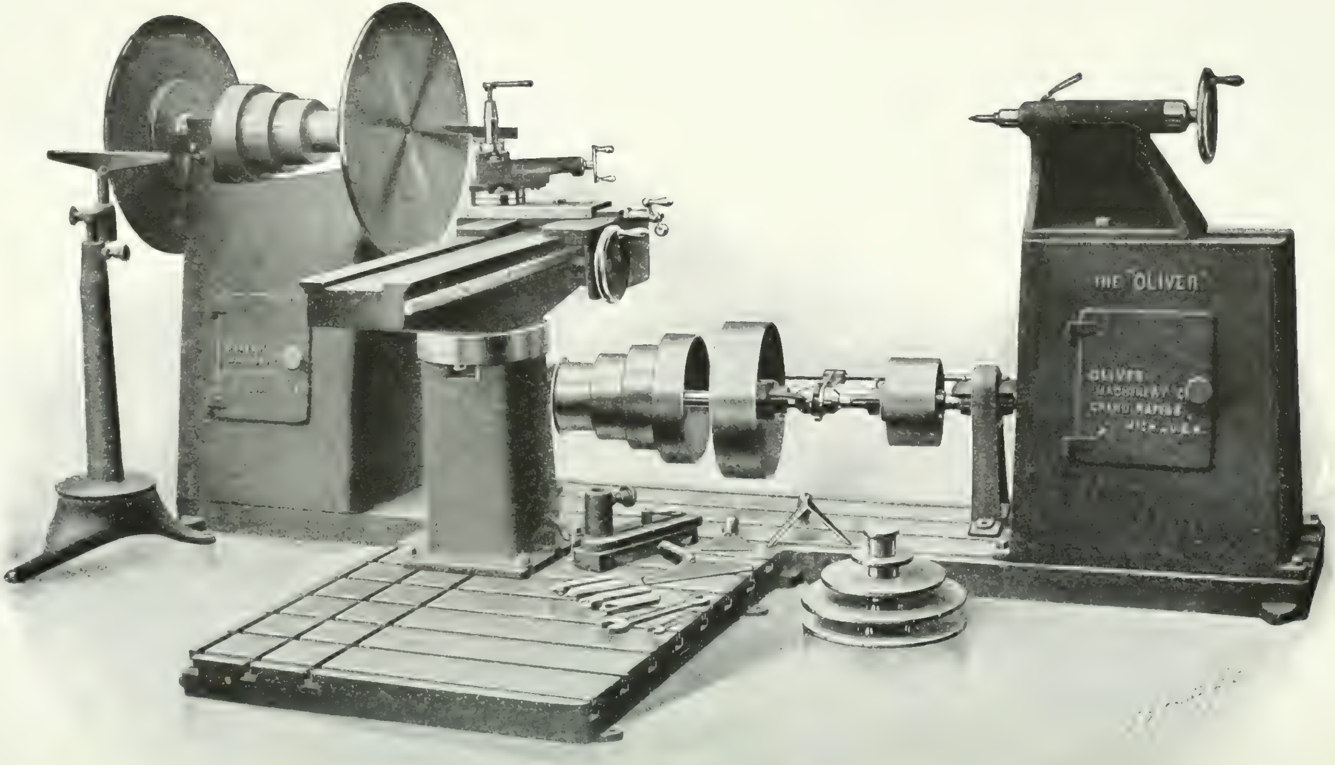


Fig. 236.

In the illustrations here given the single curve form of tooth is used.

In the construction of gear-wheel patterns, the methods employed in making and fastening the tooth, or the blocks out of which the teeth are to be formed, to the rim of the wheel, varies greatly. It was formerly the custom to dovetail the tooth into the rim of the wheel as shown in Fig. 236. This was the case especially when the teeth were large, as in 2 pitch or larger.



COMBINATION PATTERN LATHE.

This is, however, an unnecessary expense and a waste of time, and in addition, the cutting of the dovetails and the driving home of the dovetailed tooth. often have the effect of distorting the rim to some extent. A better, or at least a more economical method is to fit the tooth blocks as shown in Fig. 237, which for strength and durability is found to be in no way inferior to dovetailing, and the saving of labor and time is very great.

In this method we have always the advantage of a smooth, clean fillet at the root of each tooth, and having the grain of the wood, not only for the fillets, but also on the whole depth circle, run in the same direction as the grain of the wood which forms the tooth. This means a smoother pattern, more easily moulded, and a better casting.

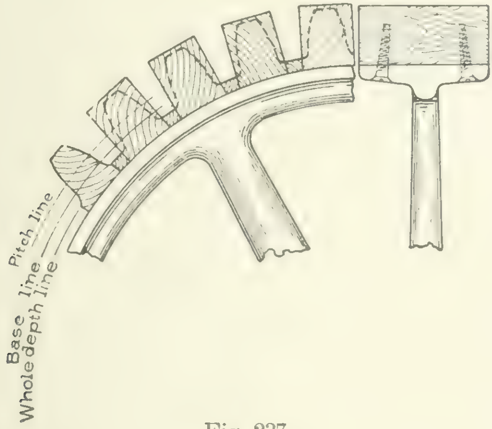


Fig. 237.

In the former method, Fig. 236, it is almost impossible to form a fillet on each side of the tooth, as it runs off to a thin feather edge which continually splinters and chips off; still further, the bottom of the tooth space, that is, the whole depth circle is the rim of the wheel, composed of layers of segments with changing grain which will not mould so smoothly as in the second method.

The blocks for the teeth should always be cut in strips two or three feet in length, in order to thoroughly season the wood, at least so far as it is possible to do so, while other parts of the wheel are being constructed.

Only straight-grained wood should be used for teeth. The segments for building up the rim should be cut out next, then the arms put together and shaped as required. It is a good plan to fasten the arms central to the face plate of the lathe, and to turn out a recess, say $\frac{1}{16}$ inch or $\frac{3}{32}$ inch deep to receive the hubs as shown in Fig. 238. This makes a stronger connection and does away with the trouble of fitting and connecting the hub, with the thin feather edge of the hub fillet, to the surface of the web of the arms. The same method is of great advantage when fitting the hubs of pulleys and other wheels. The arms must be put together, with inserted tongues in the joints, as illustrated and described in Fig. 169; and if they are to be worked to an elliptical section, it is easier to do this before fixing them in the wheel. At A, Fig. 238, the construction of the arms is shown, and at B the core prints, hubs and arms, with the manner of connecting these parts.

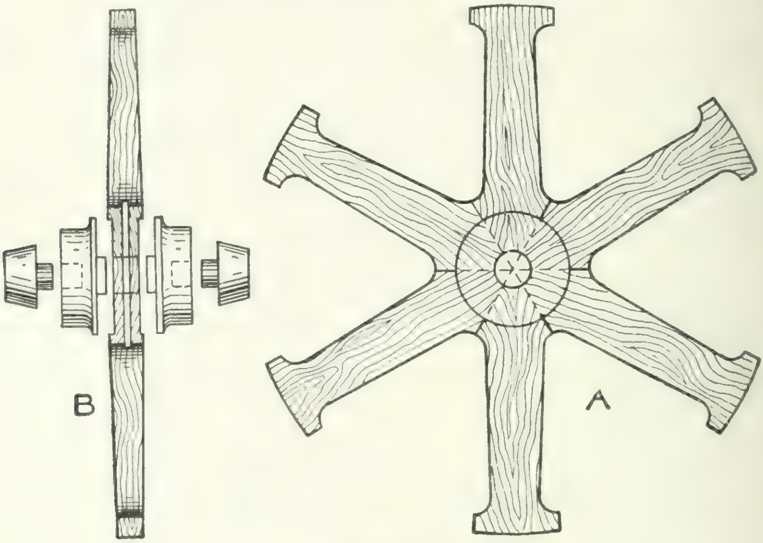
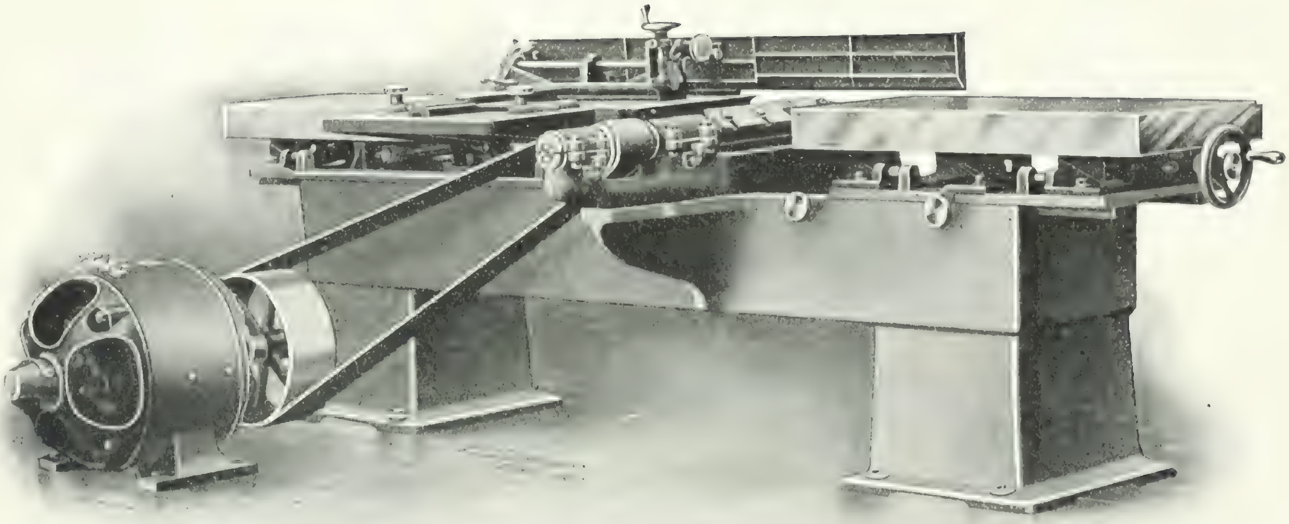


Fig. 238.

After building up enough courses of segments to equal half the width of the rim plus half the thickness of the arms, the inside only of this part of the rim is turned out to the required shape, including the central rib *a* Fig. 239, which must be of a thickness just equal to the thickness of the ends of the arms. The recesses to



HAND PLANER AND JOINTER.
Oliver Machinery Company.

receive these ends are now cut into this half rim, and the arms fitted and glued in place but not so tightly as to strain the rim and cause it to spring after it is removed from the chuck. The remaining courses for the rim are now fitted and glued on, and the rim turned and finished to the required size and shape.

The face should be glue-sized to prepare it for the blocks which are to form the teeth of the gear.

After sizing and removing the raised grain of the wood, the periphery of the wheel must be spaced for the required number of teeth. With a try square and very sharp awl draw lines through the points obtained by the spacing as shown in Fig. 240. Should the teeth be of moderate size. say 3 pitch or less, the tooth blocks should be glued on sc as tc meet each other on the rim of the wheel as shown in Fig. 241.

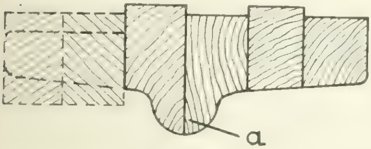


Fig. 239.

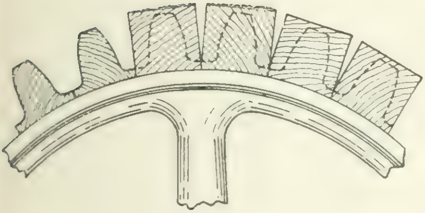


Fig. 241.

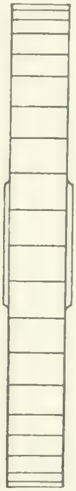


Fig. 240.

Each block must be so fitted as to reach only from line to line, Fig. 240, care being taken to have each block parallel to, and coincide with its own line, *reaching exactly to the line.* When all the blocks are placed and glued, the wheel is returned to the lathe and the periphery turned off straight and to the required diameter for the addendum, or extreme ends of the teeth. The ends of the blocks are also turned even with the edge of the wheel rim, and before removing from the lathe, a circular line must be drawn on the ends of the blocks, on both sides of the rim, indicating the whole depth of the teeth. The use of this line will be explained later; it is the only circular line needed for laying out, or for working out the teeth. When the teeth are large, a tooth block is first fitted on and screwed from the inside of the rim as shown in Fig. 237, one edge of the block touching, but not covering its line on the face of the rim. The thin strip is next fitted, glued and braded against the block with the opposite edge of the strip reaching just to, but not covering the next line. A second tooth block is fitted and screwed in place, then a second strip, and this alternate placing of blocks and strips continued until the surface of the rim is covered, having a block and strip for each tooth required.

Care must be taken not to allow any glue to get between the blocks and the strips when gluing and nailing the strips on, as each block must be taken off, one at a time, after being laid out, to work the tooth to shape. When all the blocks and strips are in place, the wheel must be returned to the lathe and the face of the blocks turned to the diameter required for the addendum or outer ends of the teeth, and the ends of the blocks also turned even with the rim.

The whole depth circles are marked, one on each side, while revolving in the lathe, as explained for a wheel with smaller teeth. All parts of the rim should now be made perfectly smooth with fine sand paper using a holder or block, to prevent rounding the corners or angles of the tooth blocks.

Beginning at the middle of a block, space the required number of teeth on the periphery of the tooth blocks, and should the first trial not result in even spaces, the trial spacing must be continued until the greatest accuracy has been obtained, that is, until all distances from point to point are exactly equal. Through each spacing point, found as above, very sharp but light lines are drawn across the face of the blocks, as was shown for the wheel rim in Fig. 240. When drawing these lines it will be found best to draw along the *inside* edge of the try square blade instead of the outside as is usual. The reason for this is that on small or medium sized wheels, a much firmer base will be given for holding the square.

and more accurate lines will be the result. A coat of shellac brushed over the ends and faces of the blocks, if sand-papered smooth after being allowed to dry, will greatly assist in laying out the teeth, hardening the surface, and enabling sharper lines to be drawn. A template must next be made of the exact form of the tooth required. This will always be given full size in the detail drawings furnished to the pattern maker.

Should the wheel be of small diameter the template may be laid out and cut on the end of a long strip of zinc, but it is better to fasten the template to the end of a wooden bar, as shown in Fig. 242 a narrow slot having been cut through the back end of the zinc to allow of exact adjustment to the diameter of the wheel.

This wooden bar is hung centrally on a peg or dowel which must be placed exactly in the center of the hub. For this purpose it is customary to use a block of wood as a temporary hub, the center of which may be easily found from the periphery of the blocks by the dividers. A very slight, sharp notch is made in the exact center of the end of the tooth template, which must be radial to the hole in the opposite end of the bar on which the template revolves. This notch is shown in Fig. 242.

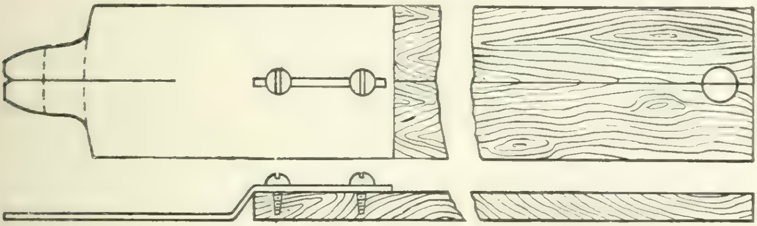


Fig. 242.

To use the template, place it over the center pin and bring the notch exactly in line with one of the spacing lines on the outside of a block and with a very sharp pointed awl mark the tooth on the end of the block. Then swing the template to the next line and mark as before, continuing the process until a tooth has been laid out on the end of each block. The wheel is now turned over and the same process repeated on the other side. It will be readily seen that if the spacing lines have been squared across the face of the wheel with accuracy, the teeth laid out on the two sides will be true and perpendicular to each other, a spacing line forming the exact center of each tooth, and for this reason these lines should always be very light but sharp and clearly defined.

For convenience in cutting and paring, a second series of lines should now be drawn across the face of each block connecting the extreme ends of the lines which describe the shape of the tooth on each end of the block. Should the wheel be small and within the capacity of the band saw, all superfluous wood may easily be removed from between the teeth.

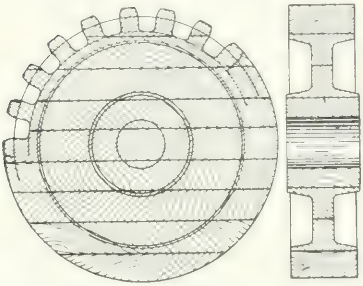


Fig. 243.

If the band saw is sharp and evenly set, and the operator skillful, the teeth may be sawed so as to need but very slight correction with the paring chisel and gouge.

As the hubs usually project beyond the rim on each side of the wheel, they should be left loose and removed before placing the wheel on the saw table.

For large wheels and heavier teeth, each tooth block should be unscrewed and removed, one at a time, and planed to the lines marked on its ends and face, after which it is returned to its place before a second one is taken off. This is continued until all the teeth are shaped, when it will be necessary only to construct fillets at the base of the teeth, and also to work each space down to the *whole depth circle*, the circle having been drawn for this purpose, and also as a guide, for bringing all tooth spaces to the same depth.

Small gears, or pinions as they are called, are usually made with a solid web instead of arms, and are glued up in solid blocks of end wood, the grain of the entire block running parallel with the face of the teeth. Such an end wood pinion is shown in Fig. 243. It is turned and the gear laid out and cut in the same way as described for the larger wheels, except that the teeth are not glued on but cut out in the solid disc. In the construction shown in Fig. 241, the teeth, not being screwed on, must be nailed with brads.

after being shaped and finished, from the face of each tooth into the rim.

Patterns for Bevel Gears are built up as illustrated at *a*, Fig. 244, the wooden face-plate, or chuck, being provided with ten or more radial blocks as shown and described in Fig. 168. The advantage of the blocks is that they keep the first layer of segments out from the face-plate and give easier access to the back edge or angle of the rim while being turned.

The segments are usually made to overlap as shown, which is not only a saving of wood but also saves the time which would be required to turn the angular rim from a square construction. When a sufficient number of courses have been built up, the face and two edges are turned to the required angles, as indicated by the dotted lines in *a*, Fig. 244. The rib *c* which will finally be a continuation of the arms, is also turned to shape and to the thickness of the ends of the arms. The rim will then present the appearance shown at *b*, Fig. 244, except the arms which are here shown in place.

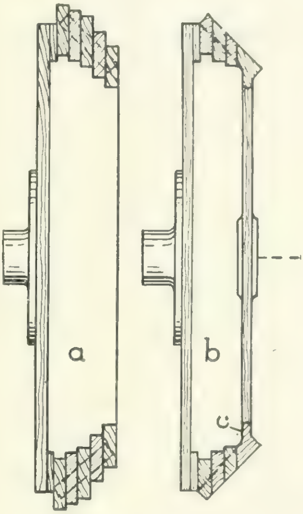


Fig. 244.

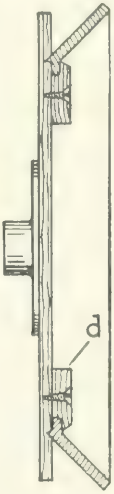


Fig. 245.

The rim is next cut from the blocks, and an angular groove turned in the face of the chuck which will fit and center the finished edge of the rim on the faceplate. In this position the inside of the rim is turned and finished as shown in Fig. 245. The rim is retained on the chuck by four or six cleats, *d*, Fig. 245, the cleats fitting over the rib *c*, Fig. 244, and preventing the rim from moving and changing its position on the chuck.

It is not necessary here to describe the method used in finding the required angles for the face and edges of the rim, but as in the case of spur-gear teeth, the student should refer to Mechanical

Drawing. The arms, partly shown in Fig. 246, in place in Fig. 244, are next fitted and fastened to the rim. It is well to glue a small disc on each side of the web of the arms as shown in Fig. 246, which not only strengthens the arms, but serves as a fillet around the hub of the wheel.

The blocks for the teeth are next fitted in place, either as illustrated in Fig, 247, or in the form of alternate blocks and strips as was shown for the spur gear, Fig. 237. After all the blocks are in place, the wheel must be put in the lathe and turned to the sizes and angles required for laying out the teeth. A sharp line must be drawn on the face of the blocks, while in the lathe, to serve as a guide for the dividers while spacing the teeth.

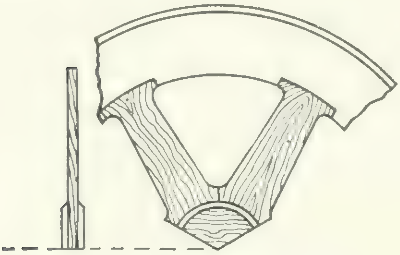


Fig. 246.

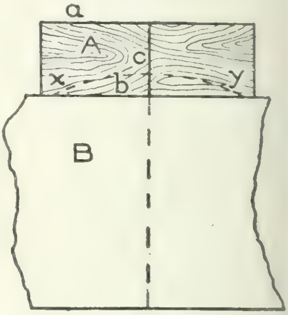


Fig. 248.

To obtain the center lines for the tooth faces after spacing on the blocks, it will be readily seen that the ordinary try square cannot be used as in the case of the spur gears. A temporary square must be made for this purpose as follows:

Take a piece of hard wood, about 6 inches long and 3½ inches wide and ½ inch in thickness. Dress the two edges perfectly parallel and from the upper edge *a*, Fig. 248, with a try square and a sharp pointed knife, draw the line *c*, equally distant from each end of A, and at right angles to the edge *a*. Lay the edge *b* of A, against another board B, of the same thickness, and continue the line *c* on this board as shown by the dotted line. With the dividers set to a radius equal to the longest radius of the outside ends of the tooth blocks, from the extended line *c* on the board B, describe the arc *x y* on A. Cut the edge *b*, to this arc and see that it fits perfectly the outer rim of the tooth block. Next make a thin blade of hard wood and screw to the head A, using the greatest care to have one edge of the blade coincide exactly with the line *e*. After screwing the blade to the head, its accuracy may be tested by placing a try square against the edge *a*. The result will be as shown in Fig. 249, in which the edge *e* is radial to the arc *x y*. This edge will describe the center lines of the teeth radially as required.

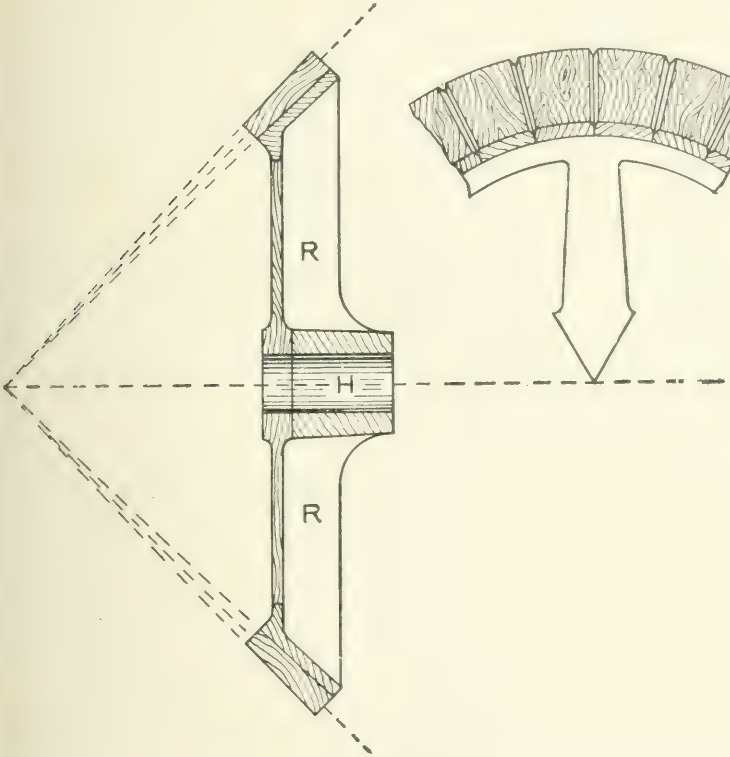


Fig. 247.

This temporary square can be used up to a certain limit, on wheels of larger diameter than that to which it has been fitted, but cannot be used for smaller wheels. For larger gears the position will be as shown in Fig. 250, which will give the correct perpendicular if the angles at *x* and *y* are carefully made. By using in this way, only a few squares will be needed for a great number of wheels. In Fig. 247 the hub H and the ribs of the arms R R, are often made loose so as to lift with the cope, which is of great advantage in moulding. When the teeth are large, they must be screwed on from the inside of the rim. If small, they should be braded from the outside, or face of the tooth, into the rim *after* the teeth have been shaped and finished. Two templates will be necessary for laying out the ends of the teeth, the outer ends being larger than the inner. These templates are made as described for spur gears, and have the outer end bent to fit over the angles of the rim.

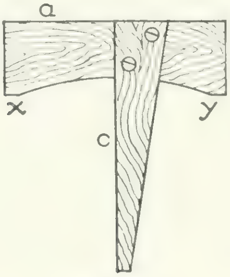


Fig. 249.

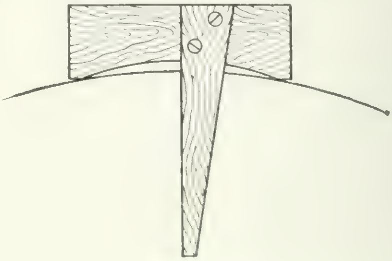


Fig. 250.

COLUMN PATTERNS

Cast-iron columns are often ornamented or fluted as shown in the half section of a fluted column in Fig. 251. In all such cases the body of the pattern is made octagonal as shown by the line A B C D E. The loose pieces forming the flutes are held to the main body by pins that stand at right angles to the line A E. After the sand has been rammed, the body included in the lines A B C D E is lifted out leaving the parts A *a b* B, B *b c* C, etc., imbedded in the sand. Then one after another these are lifted out.

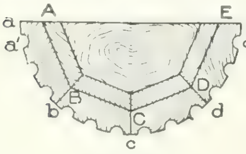


Fig. 251.

These fluted sections should never be so few in number that they cannot be lifted out without tearing the sand. Eight or twelve sections will be needed.

Other forms of ornamentation are put upon columns in a similar manner. Leaves or flowers are held by pins or in grooves in such a way that the main body of the pattern can be lifted out without disturbing them, and they are then withdrawn from the sand through the cavity left by the main pattern.

Cores for Columns. Cores for columns may be made in core boxes as in the case of those for pipe, but where the core is long and straight no core box is needed. The core is usually built of loam about an iron pipe as explained in Foundry Work.

Where the core is to follow the lines of the ornamental mouldings on the outside of the column, it may be provided with a special core box or better with a sweep as shown in Fig. 252. This sweep is used to shape the loam core that is to be built up on an iron pipe. Fig. 252 is the outline of the template that is to be used in sweeping the core for the interior of the columns shown in Fig. 253.

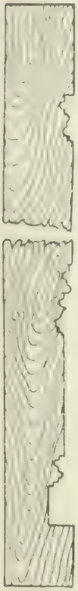


Fig. 252.

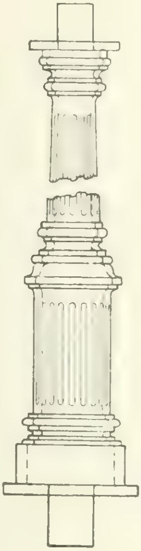


Fig. 253.

Follow Boards. All thin patterns that are likely to suffer distortion from the pressure of the sand while being rammed up, must be provided with accurately fitting follow boards. These follow boards may be made to fit on either one or other of the sides of the pattern.

When the outlines of the pattern are very irregular, the follow boards are often made of plaster or other composition, which, when dry, is used to support the pattern while the drag is being rammed.

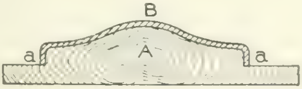


Fig. 254.

Fig. 254 represents a section of a railing cap. If the pattern B were to be set with the edges *a a* resting upon the moulding board and the sand of the drag rammed down upon its upper face, it would be sprung out of shape. To avoid this the follow board A is made to exactly fit the under side of the pattern. Then when the sand is rammed, the whole pattern is supported and there will be no distortion. When the cope is rammed the follow board is removed and the sand of the drag supports the pattern while the cope is being rammed.

FOUNDRY WORK

PART I

Foundry work is the name applied to that branch of engineering which deals with melting metal and pouring it in liquid form into sand molds to shape it into castings of all descriptions.

In the manufacture of modern machinery three classes of castings are employed, each one having its individual physical properties, such as strength, toughness, durability, etc. These castings are made from gray iron, copper alloys, *i. e.*, brass, bronze, etc., and mild steel. By far the greatest number of castings made are of gray iron, that is, iron which may be machined directly as it comes from the mold without any further heat treatment.

The main purpose of this book is to explain the underlying principles involved in making molds for gray iron castings, and the mixing and melting of the metals for such castings.

There are two other forms of iron castings. These are chilled iron, used for rolling mill rolls, car wheels, etc., and malleable iron, used for certain lines of builders' and manufacturers' hardware These are not dealt with in detail because they are rather specialities in the trade, whereas there are few towns of importance in this country in which there is no gray iron foundry.

The chapters on brass founding and steel casting will emphasize only those features of the methods used which differ from iron foundry practice.

The chapter on shop management is intended to set students thinking on this subject; because the whole trend of modern shop practice is toward specialization and system in handling every department of the work, in order to increase efficiency and reduce cost.

IRON MOLDING

There are four main branches in gray iron molding: green sand work, core work, dry sand molding, and loam work.

Green sand molding is the cheapest, quickest method of making the general run of castings. Damp molding sand is rammed over the pattern. Suitable flasks are used for handling the mold. When the pattern is withdrawn the mold is finished and the metal poured while the efficiency of the mold is still retained by reason of this dampness. The mold may be poured as soon as made. In case of necessity the mold may be held over a day or more depending upon its size. If the sand dries out, the mold should not be poured.

Core making supplements molding. It deals with the construction of separate shapes in sand which form holes, cavities, or pockets in the castings. Such shapes are called cores. They are held firmly in position by the sand of the mold itself. Core sand is of a different composition from molding sand. It is shaped in wooden molds called core boxes. All cores are baked in an oven before they can be used The whole detail of their construction is so different from that of a mold, that core making is a distinct trade. A trade, however, that is generally considered a stepping stone to that of molding. Boys usually begin to serve their time in the core shop.

Dry sand is the term applied to that class of work where a flask is used, but a layer of core sand mixture is used as a facing next to pattern and joint and the entire mold is baked before pouring. This drives off all moisture and gives hard, clean surfaces to shape the iron. It is used where heavy work having considerable detail is to be cast, or where the rush of metal or the bulk of it might injure a mold of green sand. Dry sand molds are usually made up one day, baked over-night, and assembled and cast the next day.

Loam work is the term applied to molds built of bricks carried on heavy iron plates. The facing is put on the bricks in the form of mortar and shaped by sweeps or patterns depending upon the design of the piece to be cast All parts of the mold are baked, rendering the surfaces hard and clean. After being assembled, these brick molds must be rammed up on the outside with green sand in a pit or casing to prevent them bursting out under the casting pressure. Simple molds can be made up one day, assembled, rammed up and poured the next but it usually takes three or four days and sometimes as many weeks to turn out a casting.

Loam work is used for the heaviest class of iron castings for which, on account of the limited number wanted, or the simplicity of the shape, it would not pay to make complete patterns and use a flask.

In some cases the intricacy of the design makes a pattern necessary, and size alone excludes the use of sand and flasks.

No hard and fast rules exist for the selection of the method by which a piece will be molded. Especially with large work the question whether it shall be put up in green sand, dry sand, or loam, often depends upon local shop conditions. The point to consider is: How can the best casting for the purpose be made for the least money, considering the facilities at hand to work with?

MATERIALS

Before taking up the making of molds, let us consider briefly the materials used, where they are obtained, and what is their particular service in the mold. Also we shall describe the principal tools used by the molder in working up these materials into molds.

There are three general classes of materials for molding kept in stock in the foundry. These are:

SANDS

- Molding sands
  - Light
  - Medium
  - Strong
- Free sands
  - Sharp or Fire
  - Beach sand

FACINGS

- Graphite
- Charcoal
- Sea coal

MISCELLANEOUS

- Fire clay
- Parting dust
  - Burnt sand
  - Charcoal
  - Partainol
- Core binders

SANDS

All sands are formed by the breaking up of rocks due to the action of natural forces, such as frost, wind, rain, and the action of water.

Fragments of rocks on the mountain sides, broken off by action of frost, are washed into mountain streams by rainfall. Here they grind against each other and pieces thus chipped off are carried by the rush of the current down into the rivers. Tumbled along by the rapid current of the upper river, the sand will finally be deposited where the stream flows more gently through the low land stretches below the hills. Here the slight agitation tends to cause the finer sand and the clay to settle lower and lower down in the bed. Thus we find beds that have been formed in ages past; possibly with a top soil formed over them, so long have they been deposited. But on removing this top soil we find gravel or coarse sand on top; this merges into finer sand and this again finally into a bed of clay.

Rocks, however, are very complex in their composition, and sands contain most of the elements of the rocks of which they are fragments. For this reason molding sands in different parts of the United States vary considerably.

A good molding sand should, first of all, be refractory, that is, capable of withstanding the heat of molten metal. It should be porous to allow the escape of gases from the mold. It should have a certain amount of clay to give it "bond" or strength, and should have an even grain. All of these properties will vary according to the class of work for which the sand is used.

The two important chemical elements in such sands are silica, which is the heat-resisting element, and alumina, or clay, which gives the bond. Other elements which are found in the molding sands are oxide of iron, oxide of lime, lime carbonate, soda potash, combined water, etc. The following analyses, by W. G. Scott, will give an idea of the proportion of these elements in the different foundry sands:

CHEMICAL SYMBOLS	FIRE SAND	MOLDING SANDS				CORE SAND
		Iron Work			Brass	
		Light	Medium	Heavy	Light	
a. Silica .... SiO_2	98.04	82.21	85.85	88.40	78.86	85.50
Alumina (clay) .... Al_2O_3	1.40	9.48	8.37	6.30	7.89	2.65
Iron oxide .... Fe_2O_3	.06	4.25	2.32	2.00	5.45	.85
Lime oxide .... CaO	.20	....	.50	.78	.50	....
b. Lime carbonate .... $CaCO_3$	....	.68	.29	....	1.46	2.65
Magnesia .... MgO	.16	.32	.81	.50	1.18	4.27
Soda .... Na_2O	....	.09	.10	....	.13	.04
Potash .... K_2O	....	.05	.03	....	.09	.04
Combined water .... H_2O	.14	2.64	1.68	1.73	3.80	2.00
Organic matter		.28	.15	.04	.64	1.00
Specific gravity	2.592	2.652	2.645	2.630	2.640	
Degree of fineness		85.	66.	46.	95.	

Silica alone is a fire-resisting element, but it has no bond. These other elements help in forming the bond. But under heat, silica combines and fuses with them, forming silicates. These silicates melt at a much lower temperature than does free silica. Therefore with sands carrying much limestone in their make up, or those containing much oxide of iron, soda potash, etc., the molten iron will "burn in" more, making it more difficult to clean the castings.

The limestone combinations also go to pieces under heat, tending to make the sand crumble, which may result in dirty castings.

The proportions given in the above table must not be considered as absolutely fixed, for no two samples of sand, even from the same bed, will analyze exactly alike. The table is instructive, however, because it shows the reason why the different sands are especially adapted to the use to which they are put in practice; as for example:

Fire Sand is used in the daubing mixture for repairing inside of cupola and ladles, and should be in the highest degree refractory, and should contain as little matter as possible that would tend to make it fuse or melt.

Light Molding Sand is used for castings such as stove plate, etc., which may have very finely carved detail on their surfaces, but are thin. The sand should be very fine to bring out this detail; it must be strong, *i. e.*, high in clay, so that the mold will retain every detail as the metal rushes in. On the other hand, the work will cool so quickly that after the initial escape of the air and steam there will be very little gas to come off through the sand.

Medium Sand is used for bench work, and light floor work, making machinery castings having from ½ to 2-inch sections.

These will have less fine detail, so the sand may be coarser than in the previous case. The bond should still be fairly strong to preserve the shape of the mold, but the tendency of the large proportion of clay to choke the vent will be offset by the larger size of the grain. This vent must be provided for because the metal will remain hot in the mold for a longer time and will cause gases to form during the whole of its cooling period.

Heavy Sand is used for the largest iron castings. Here the sand must be high in silica and the grain coarse because the heat of the molten metal must be resisted by the sand and gases must be carried off through the sand for a very long time after pouring. The amount of bond or clay must be small or it will cause the sand to cake and choke these gases. The detail is generally so large that the lack of bond is compensated for by the use of gaggers, nails, etc. The coarse grain is rendered smooth on the mold surface by careful slicking.

Core Sand, often almost entirely surrounded by metal, must be quite refractory but have very little clay bond. This bond would make the sand cake, choking the vent, and render it difficult of removal from a cavity when cleaning the casting. Compared with medium molding sand it shows higher in silica although having less than half the proportion of alumina.

Sands having practically no clay in them are called *free sands*. Of these there are two kinds in use, *river sands* and *beach sands*.

The grains of river sand retain the sharp fractured appearance of chipped rock, and these little sharp grains help much in making a strong core because the sharp angular grains interlock one with another. River sand is used on the larger core work. Beach sand is considerably used in coast sections because it is relatively inexpensive, but its grains are all rounded smooth by the incessant action of the waves. It will pack together only as will so many minute marbles. For this reason it is used only for small cores.

FACINGS

Foundry facing is the term given to materials applied to or mixed with the sand which comes in contact with the melted metal. The object being to give a smooth surface to the casting. They accomplish this in two ways: 1st, by filling in the pores between the sand, thus giving a smooth surface to the mold face before the metal is poured; 2nd, they burn very slowly under the heat of the metal, forming a thin film of gas between sand and iron during the cooling process. This prevents the iron "burning into" the sand and causes the sand to separate from the casting when cold.

Different forms of carbon are used for this purpose because carbon will glow and give off gases, but it will not melt. The principal facings are *graphite, charcoal,* and *sea coal.*

Graphite is a mineral form of carbon. It is mined from the earth and shipped in lumps which are blacker than coal and soft and greasy like a lump of clay. The purest graphite comes from the Island of Ceylon, India. There are several beds, however, in the coal fields of North America.

Charcoal is a vegetable form of carbon. It is made by forming a shapely pile of wood, covering this over with earth and sod, with the exception of four small openings at the bottom and one at the top The pile is set on fire and the wood smoulders for days. This burns off the gases from the wood, leaving the fibrous structure charred but not consumed. Charcoal burning is done in the lumbering districts. 'The charcoal for foundry facings should be made from hard wood

Although sea coal contains a high per cent of carbon, it is less pure than the other facings and will give off much more gas. Sea coal is made from the screenings from the soft coal breakers. The coal should be carefully selected by the manufacturer and be free from slate and very low in sulphur.

All facings are manufactured by putting the raw materials through a series of crushers, tumbling mills or old-fashioned burr stone mills, and then screening them. The finest facings are bolted much as flour is.

In the shop the molder distinguishes between facings or blackings, and facing sand. The former consists of graphite or charcoal, and is applied to the finished surface of a mold or core. The latter is the name given to a mixture of new sand, old sand, and sea coal which in the heavier classes of work form the first layer of sand next the pattern.

The use of the different facings will be clearly seen from the following table:

MATERIAL	USES	ACTION
Charcoal.	Good facing for light molds; dusted on from bag after pattern is drawn.	Burns at low enough temperature to be effective before thin work cools.
	Mixed with molasses water for wash for small cores and dry sand work.	
	Mixed with some graphite and clay wash for blacking for heavy dry sand and loam work; slicked over with tools.	Resists moisture; prevents sand surfaces from sticking together.
	May be used as a parting dust on joint of bench molds.	
Graphite.	Good facing for bench molds; dusted on from bag; good for medium and heavy green sand work. Applied with camel's hair brush, and slicked over with tools.	Good on heavier green sand because it is more refractory than charcoal, but still forms gas enough to keep metal from burning into sand.
	For heavy blacking for dry sand and loam work. See above.	
Sea Coal.	Mixed with facing sand in proportions 1—6 to 1—12. See section on molding.	Helps to force vents through sand when mold is first poured, and prevents strong sand of the facing from caking, because it continues to throw off gas after casting has solidified.

MISCELLANEOUS MATERIAL

Fire Clay comes from the same source that sand does. It is almost pure oxide of alumina, which is separated out from the sand by a combination of the chemical and mechanical action of the waters of the streams. Fire clay has traces of the other impurities mentioned in the analysis of molding sands. It is found in the lowest strata of the deposit beds.

It is used to mix with fire sand in the proportion of 1 to 4 as the daubing mixture for cupola and ladles.

Clay Wash—fire clay and water. The test for mixing this is as follows: Dip the finger into the wash and then withdraw it. There should be an even film of clay deposited on the finger.

Clay wash is used as the basis of heavy blackings. It is used for wetting crossbars of flasks; breaks in sand where a repair is to be made; to wet up the dry edges of ladle linings when repairing with fresh daubing mixture; in fact, any place where a strong bond is required at some particular spot.

Parting Sands or parting dusts must contain no bond. They are used to throw on to the damp surfaces of molds which must separate one from another. They prevent these surfaces formed of high bond sands from sticking to each other.

The cheapest parting sand, and by far the most commonly used, is obtained by putting some burnt core sand, from the cleaning shed, through a fine sieve.

Beach sand is also used as a parting sand, but the rounded nature of its grain weakens the molding sands more than does burnt core sand

Charcoal facing dusted from a bag makes an excellent parting dust on fine work.

A dust manufactured expressly for the purpose and called "Partainol" is the most perfect material for fine work. This is applied from a dust bag It is not only useful for sand joints, but is a great help if there is a deep lift on a pattern where the sand is liable to stick; or for a troublesome box in the core room.

Core Binders. Although the materials for this purpose, flour, rosin, oil, etc., are on the purchasing list of the general foundry buyer, for the purposes of this paper they will be explained in detail in the section on Core Work.

TOOLS

Under this heading only the hand tools and equipment used by the molder in putting up his mold, will be described. The mechanical appliances for reducing labor are described in a later section.

To use sand economically for molds, sets of open frames called flasks are used. *Flasks* consist of two or more such boxes. The lower box is called the *drag* or *nowel*, the upper box is called the *cope*. If there are intermediate parts to the flask they are called *cheeks*. Flasks are fitted with pins and sockets so that they will always register.

For small castings the molds are rammed up on benches or projecting brackets. Such work is termed bench work and the flasks are usually what are known as snap flasks. They range in size from 9 x 12 inches to 18 x 20 inches. As will be seen from Fig. 1, these flasks hinge on one corner and have catches on the diagonal corner. The advantage of the snap flask is that with but one flask any number of molds may be put up, and the flask removed as each mold is completed. There are several good snap flasks to be had on the market. Many foundries, however, make up their own.

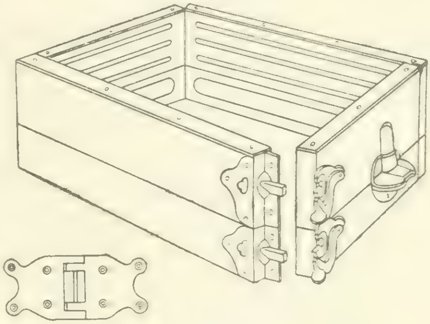


Fig. 1. Snap Flask.

Each size of flask should have at least one smooth straight board called the mold board, the size of outside dimensions of the flask. Rough boards or bottom boards of same size should be provided, one for each mold that will be put up in a day.

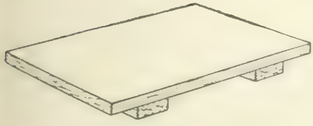


Fig. 2. Mold Board.

Boards for snap work are made from $\frac{7}{8}$ to 1 inch stuff, and should have two stiff cleats, as shown in Fig. 2, to hold them straight.

For heavier castings where the molds are made on the floor, box flasks are used made of wood or iron.

In the jobbing shop, wood flasks are more economical, as they can more readily be altered to fit a variety of patterns, while in a foundry turning out a regular line of castings, iron flasks pay because they require less repair.

Wooden flasks of necessity receive hard usage in the shop and grow weaker each time they are used. They will burn more or less each heat; they receive rough usage when the mold is shaken out; and often the flasks must be stored where they are exposed to all kinds of weather. It is economy, therefore, to build wooden flasks heavier than would be necessary if they were always to be used in their new condition.

Fig. 3 shows construction of a typical wooden flask; the sides project to form lifting handles, the ends are gained in to the sides. Through bolts hold the sides firmly in addition to the nailing. Detail of the pin is shown at A, and at B is a cast-iron rocker useful on flasks over 4 x 5 feet, to facilitate lifting and rolling over. The cleats make it a simple matter to alter crossbars. The crossbars should be not over 8 inches on centers. For more than 3-foot spans they should have short crossbars through the middle connecting the long ones. In flasks 4 feet and over there should be one or more iron crossbars and a ½-inch through bolt with good washers to clamp the sides firmly to them.

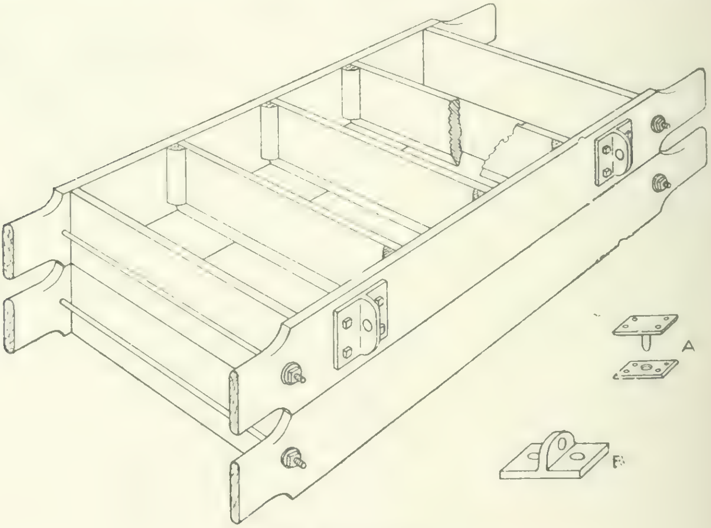


Fig. 3. Wooden Flask.

The following table shows thickness of stuff for sides and cross-bars for average sizes of jobbing flasks:

Flask Sizes, 6 Inches Deep	Sides	Cross-bars	Short Cross bars	Iron Cross-bars
Up to 24 x 24 ins.	1½ in.	1 in.		
18 ins. to 24 ins. wide to 5 ft. long	2 ins.	1 in.		1
24 ins. to 36 ins. " " 6 " "	2½ in.	1¼ in.	1 row	2
36 ins. to 48 ins. " " 7 " "	3 ins.	1½ in.	2 rows	2

N. B.—For each additional 6-inch depth of cope or drag, add 25 per cent to the thickness given.

Example. Find thickness of sides and bars in a flask 30 x 48 inches.

Length on side over 2 ft. under 5 ft. *Thickness of side* = 2 inches.

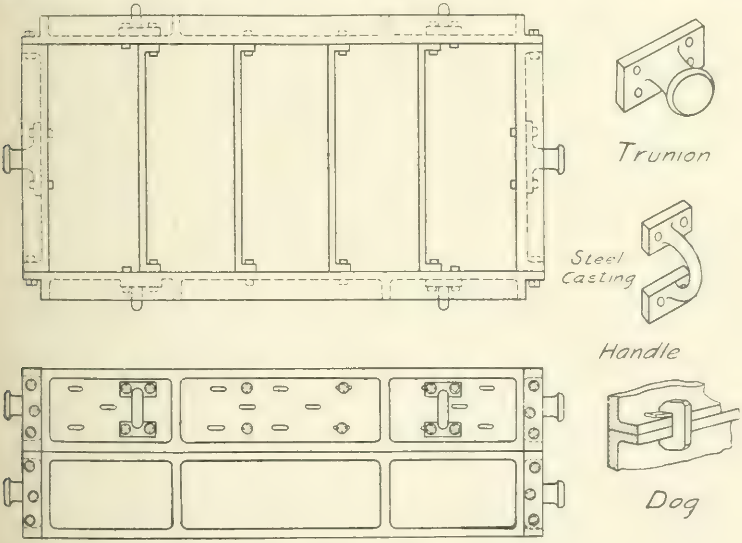


Fig. 4. Iron Flask.

Width of flask over 24 inches under 36 inches, *Thickness of crossbar* = 1¼ inches.

Fig. 4 shows the construction of a large iron flask suitable for dry sand work. The pieces of the flask are usually cast in open sand from a skeleton pattern, all holes cored in. The crossbars are cast in the same way; they have a slot in the flange instead of holes to facilitate adjusting them. Trunnions and rockers are sometimes cast on the sides in a core instead of being made separate and bolted on. Holes for pins are usually drilled through the joint flange. For pins, short iron bars are used temporarily in closing. Thickness of metal varies from ⅞ to 1¼ inches according to size of flask.

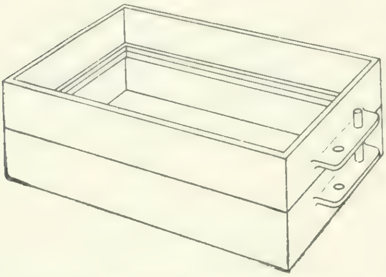


Fig. 5. Flask for Molding Machine.

Fig. 5 shows typical form of iron flask used on some molding machines. The boxes are cast in one piece. The handles serve as lugs for the closing pins. Only one pin is fixed on each box. This makes the boxes interchangeable and capable of being used for either cope or drag.

For cutting and handling loose sand the molder uses a shovel with flat blade, Fig. 6, for it is often more convenient to let the sand slide off of the side of the shovel than off of the end. This is especially true when shoveling sand into bench molds or molding machine flasks.

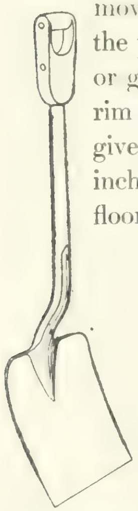


Fig. 6. Flat Blade Shovel.

The foundry sieve or riddle, Fig. 7, is used to break up and remove lumps, shot iron, nails, etc., from the sand placed next the pattern or joint. Sieves should have oak rims with brass or galvanized iron wire cloth. In ordering, the diameter of rim and number of meshes to the inch of the woven wire is given. Good sizes for the iron foundry are 16 inches to 18 inches diameter, No. 8 to 12 on bench work, No. 4 to 8 on floor work.

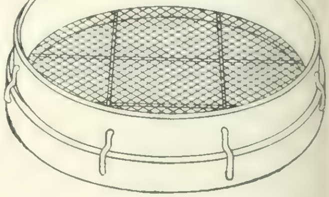


Fig. 7 Foundry Sieve.

Rammers are used for evenly and quickly packing the sand in the flask. One end is in the shape of a dull wedge, called the peen end, the other is round and flat, called the butt end. In Fig. 8, *a* is the type of rammer used on bench work; *b* is a floor rammer having cast heads and wooden shaft; *c* shows rammer made up in the foundry by casting the heads on the ends of an iron bar; *d* shows small peen cast on short rod; this is convenient for getting into corners or pockets on floor work.

In shops equipped with compressed air a pneumatic rammer is sometimes used to butt off large flasks, and for ramming loam molds in pits. See Fig. 9.

Molders' tools are designed for shaping and slicking the joint surfaces of a mold and finishing the faces of the mold itself. Except the trowels, they are forged in one piece from steel. The trowels have steel blade and short round handle which fits conveniently into the grasp of the hand. All of the tools are ground slightly crowning on the bottom. They are rocked just a little as they are worked back and forth over the sand to prevent the forward edge cutting into the surface of the mold.

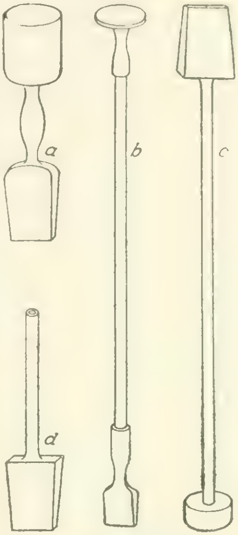


Fig. 8. Rammers.

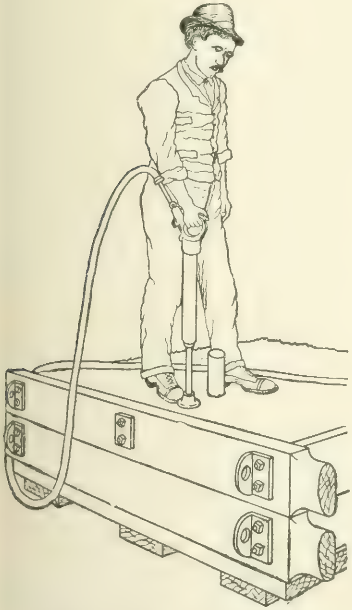


Fig. 9. Pneumatic Rammer.

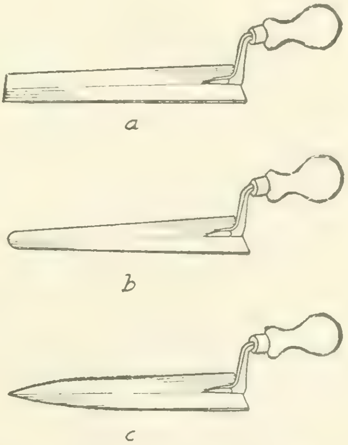


Fig. 10. Trowels.

Of the sixty or more combinations of shapes on the market, the few illustrated represent the ones most commonly used in jobbing shops.

Trowels, Fig. 10, are used for shaping and smoothing the larger surfaces of a mold. The square trowel (*a*) is convenient for working up into a square corner, and the finishing trowels (*b* and *c*) are more for coping out and finishing along the curved edges of a pattern. Trowels are measured by the width and length of blade.

Slicks are designated by the shape of the blade and the width of the widest blade. In Fig. 11, *a* is a heart and leaf; *b*, leaf and spoon; *c*, heart and square; and *d*, a spoon and bead. These are in sizes of 1 inch to $1\frac{3}{4}$ inches. They are used for repairing and slicking small surfaces

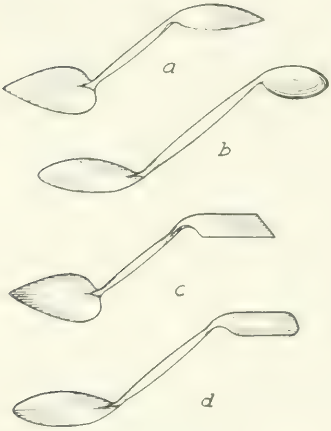


Fig. 11. Slicks.

Fig. 12 shows lifters used to clean and finish the bottom and sides of deep narrow openings; *a* is a floor lifter, made in sizes $\frac{1}{8}$ x 10 to 1 x 20; *b* is a bench lifter, sizes vary from $\frac{3}{16}$ inches to $\frac{3}{4}$ inch.

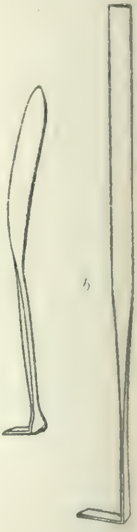


Fig. 12. Lifters.

Fig. 13 shows at *a* and *b*, inside and outside square corner slicks, made in sizes of 1 to 3 inches. *c* is a half round corner, widths 1 inch to $2\frac{1}{2}$ inches; and *d* is a pipe slick made 1 inch to 2 inches. This style of tool is mainly used on dry sand and loam work.

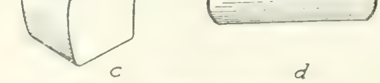


Fig. 13. Square Corner Slicks.

Swabs are used to moisten the edges of the sand about a pattern before drawing it from the mold.

This foundry swab is a dangerous though useful tool. Its danger lies in a too free use of water around the mold, which may result in blow holes. A good swab for bench work is made by fastening a piece of sponge, about double the size of an egg, to a goose quill or even a pointed hardwood stick. The point will act as a guide and the water may be made to run or simply drop from the point by varying the pressure on the sponge. Floor swabs, Fig. 14, are made from hemp fiber. They should have a good body of fiber shaped to a point, and be made about 12 inches or 14 inches long. They will take up considerable water and deliver it from the tip of the point. In heavy work the swab is trailed lightly over the sand like a long bristled brush.

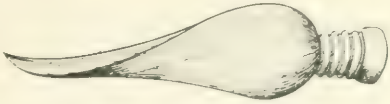


Fig. 14. Floor Swab.

Vent wires are used to pierce small holes through the sand connecting the mold cavity with the outside air. For bench work a knitting needle is the most convenient thing to use. It should have a short hardwood handle or cast ball on one end. Select a needle as small as possible, so long as it will not bend when using it.

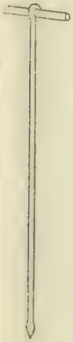


Fig. 15. Vent Rod.

Heavy vent rods are best made of a spring steel from $\frac{3}{16}$ inches to $\frac{1}{2}$ inch with the pointed end enlarged a little to give clearance for the body of the rod when run deep into the sand. See Fig. 15.

Draw sticks are used to rap and draw patterns from the sand. Fig. 16 shows three kinds: (*a*) is a small pointed rod $\frac{1}{4}$ inch to $\frac{3}{8}$ inch in size, which gets its hold by simply driving it into the wood of the pattern. (*b*) is a wood screw welded to an eye for convenience. (*c*) is an eye rod with machine screw-thread, which requires a metal plate let into the pattern. The plate is called a rapping plate and is made with separate holes not threaded. Into these holes a pointed rapping bar is placed when rapping the pattern. This preserves the threads used for the drawbar.

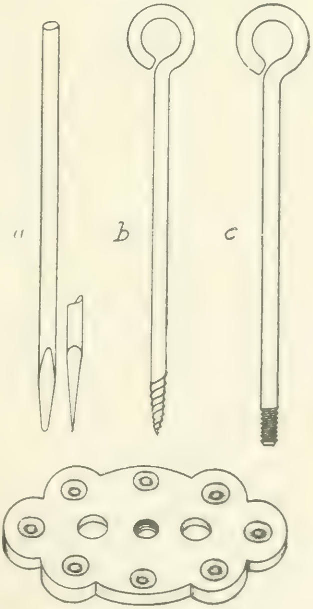


Fig. 16. Draw Sticks.

In pouring, the parts of a mold must be clamped by some method to prevent the pressure of the liquid metal from separating them, causing a run-out.

For light work a weight, shown in Fig. 17, is the most convenient. This is simply a plate of cast iron 1 inch to $1\frac{1}{2}$ inches thick, with a cross-shaped opening cast in it to give considerable liberty in placing the runner in the mold. The weights are from 15 to 40 pounds, according to size of flasks.

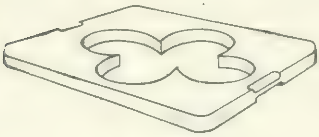


Fig. 17. Weight

Floor flasks are fastened with clamps made of cast iron. These are tightened by prying them on to a hardwood wedge. Fig. 18 shows how wedge may first be entered and how the clamping bar is used to firmly clamp the flask. For iron flasks used in dry sand work the clamps are very short as only the flanges are clamped together. See Fig. 4. Iron wedges are used instead of wood. Often the iron bottom board is clamped on and the joint flanges bolted together before pouring.

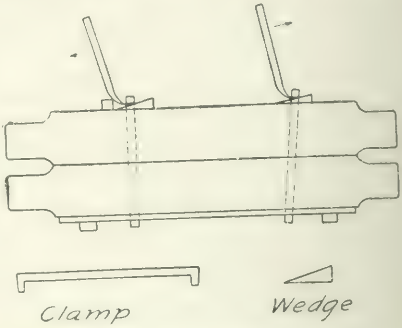
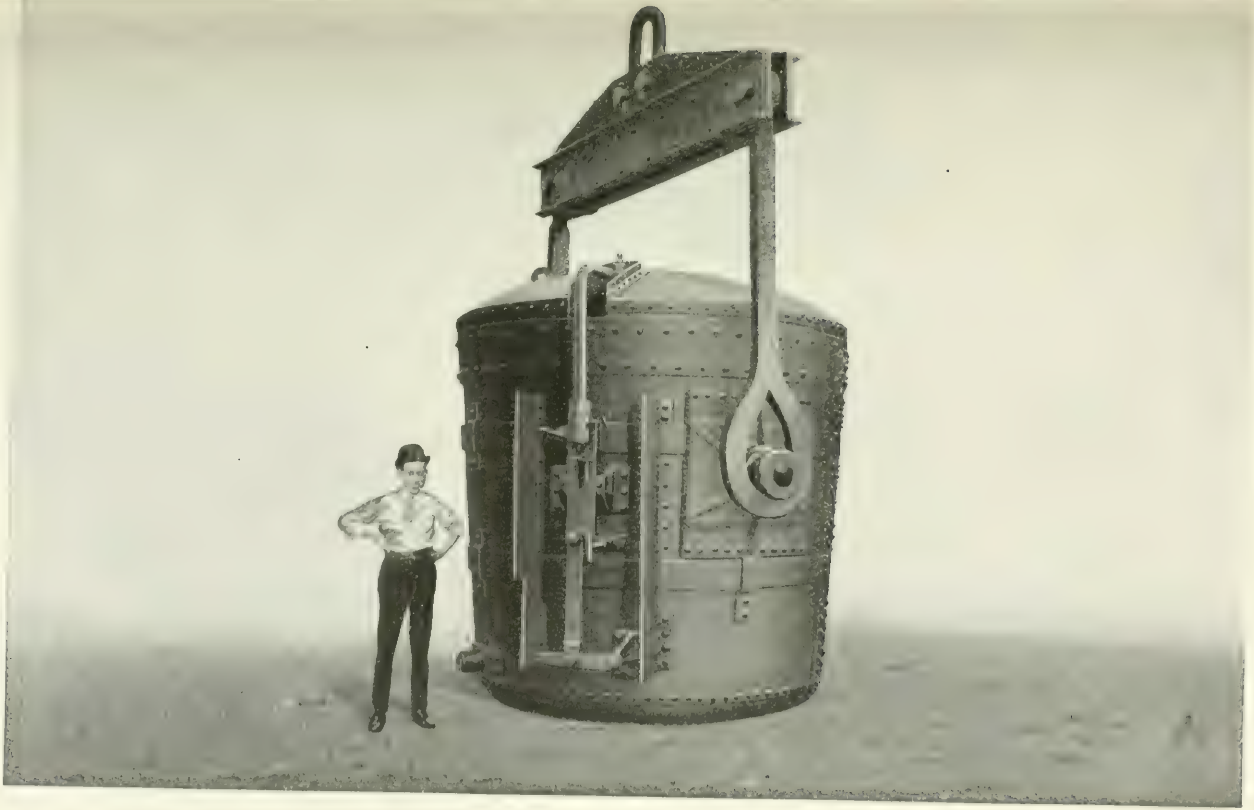


Fig. 18. Method of Clamping.

PRINCIPLES OF MOLDING

There are certain *principles* underlying iron molding which hold good in all classes of founding, and a practical understanding of these principles is necessary for good work in any line.

Aside from the fact that we generally want a mold which takes the least possible time to put up, there are three things aimed at in green sand work, these are: A *sound casting*, free from internal imperfections, such as blow holes, porous spots, shrinkage cracks, etc. A *clean casting*, free from dirt, such as slag, sand, etc. A *smooth casting*, having uniform surface free from scabs, buckles, cold shuts, or swells. The natural sands best adapted to obtain these results have already been dealt with. The methods of adding new sands vary with different classes of work. For light work the entire heap should be kept in good condition by adding a little new sand every day; for the light castings do not burn out the sand to a great extent.



50-TON LADLE.

The William B. Pollock Co.

On heavier work of from 50 pounds and upward, the proportion of sand next the pattern is so small compared with that used simply to fill the flask, that it does not pay to keep the entire heap strong enough for actual facing. The heap should be freshened occasionally with a cheap molding sand, but for that portion of the mold which forms the joint surface and especially that which comes in contact with the metal, a facing sand should be used.

The range of new sand in facing mixtures is

$$\left.\begin{array}{l}\text{3 to 6 New sand}\\ \text{6 to 2 Old ``}\\ \text{1 to 2 Free ``}\end{array}\right\}\tfrac{1}{6}\text{ to }\tfrac{1}{8}\text{ Sea coal facing.}$$

These proportions, and the thickness of the layer of facing sand, vary with the weight of metal in the casting. Too much new sand tends to choke the vent and cause sand to cake; too little new sand renders facing liable to cut or scab. Too much sea coal makes sand brittle, and more difficult to work, also gives off too much gas which is liable to cause blow holes in casting. Not enough sea coal allows the sand to cake, making cleaning difficult.

To prepare foundry sand for making a mold, it must be "tempered" and "cut" through. This is now usually done by laborers.

To temper the sand, throw water over the heap in the form of a sheet by giving a peculiar backward swing to the pail as the water leaves it. Then "cut" the pile through, a shovelful at a time, letting the air through the sand and breaking up the lumps. This moistens the clay in the sand, making it adhesive and puts the pile in the best condition for working.

To test the temper, give one squeeze to a handful of sand. An excess of water will at once be detected by the soggy feeling of the sand. Now hold the egg-shaped lump between thumb and finger of each hand and break it in the middle. The edges of the break should remain firm and not crumble.

Too much moisture will make excess of steam in the mold, causing blow holes. Not enough moisture renders sand weak and apt to wash or cut.

Bearing in mind the nature of the materials we have to work with, we must now study the important *operations* involved in making a sand mold.

The sand next to the joint and over the pattern should be *sifted*. The thickness of this layer of sifted sand varies from about $\frac{3}{4}$ inch for light work, to 2 inches on very heavy work. The fineness of the sieve used depends upon the class of work. No. 16 or 12 would be used for small name plates, stove plate, etc., while No. 8 or 6 is good for general machinery work. On floor work, from 4 to 6 inches of sand back of the facing should be riddled through a No. 4 sieve to ensure more even ramming and venting.

RAMMING

The object of *ramming* is to make the sand hang into the flask and support the walls of the mold against the flow and pressure of the metal. The knack of ramming just right only comes with continued practice and comparison of results. Hard ramming closes up the vent, causing blow holes. Iron will not lay—to a hard surface. Soft ramming leaves a weak mold surface and the flow of the metal as it enters the mold will "wash" or "cut" the sand, leaving a "scab" on one part of the casting and sand holes on another. A mold rammed too soft will tend to "swell" under the pressure of the liquid metal,

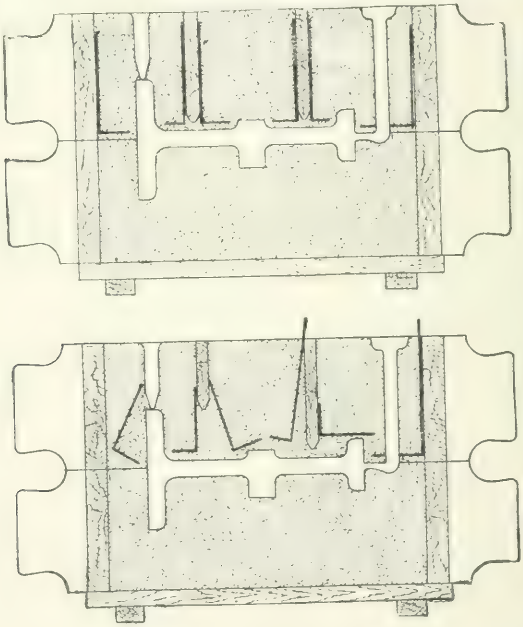


Fig. 19. Setting Gaggers.

making the casting larger than the pattern or leaving an unsightly lump on the casting. The bottom parts of a mold being under greater casting pressure must be rammed somewhat harder than the upper portions.

The joint also should be packed firmly, as it is exposed to more handling than any other part.

Crossbars are put in the cope to make it possible to lift the sand with the cope without excessively hard ramming. As an additional support for the cope sand on large work *gaggers* are used. These are L-shaped pieces of iron made from wrought or cast iron of from $\frac{5}{16}$-inch to $\frac{1}{2}$-inch square section.

The force of the sand pressing against the long leg of the gagger holds it in place and the short leg supports the sand about it. Therefore the gagger will hold best when the long leg is placed tight against the crossbar and plumb. The long leg of the gagger should not project above the level of the cope, as there is much danger of striking it and breaking in the mold after the flask is closed. Fig. 19 shows the right and the wrong ways of setting gaggers.

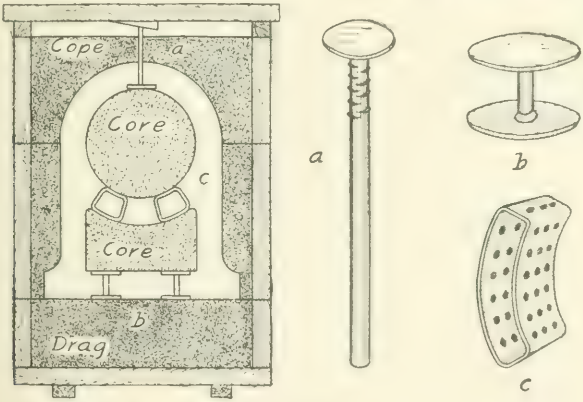


Fig. 20. Chaplets.

Chaplets should be used to support parts of cores which cannot be entirely secured by their prints which are held in the sand of the mold. Fig. 20 shows the three principal forms of chaplets used, and how they are set in the mold; (*a*) is a stem chaplet; (*b*) is a double headed or stud chaplet; and (*c*) is a form of chaplet made up of strip metal.

That portion of the chaplets which will be bedded in metal is tinned to preserve it from rusting, because rusty iron will cause liquid metal to "blow." For small cores nails are often employed for this purpose, but only new ones should be used. With the stem chaplets the tails must be cut off when the casting is cleaned—the stud chaplet becomes entirely embedded in the metal. There are now manufactured and on the market many different styles of chaplets. In selecting the size and form for a given purpose the *head* of the chaplet should be large enough to support the weight of the core without crushing into the sand and thin enough to fuse into the liquid metal. The *stem* must be small enough to fuse well to the metal and stiff enough not to bend, when hot, under its load.

VENTING

In the section on sands, reference has already been made to gases which must be taken off from a mold when it is poured. There are three forms of these: *Air*, with which the mold cavity is filled before pouring; *Steam*, formed by the action of the hot metal against the damp sand during the pouring process; and *Gases*, formed while the casting is cooling, from chemical reactions within the liquid metal and from the burning of organic matter, facings, core binder, etc., in the sands of the mold. It is of the greatest importance that these gases pass off quickly and as completely as possible. If they do not find free escape through the mold they are forced back into the liquid metal, making it "boil" or "blow." This may blow the metal out through risers and runners, or simply form numerous little bubble-shaped cavities in the casting, called "blow holes." These often form just below the skin of the casting and are not discovered until the piece is partially finished.

We cannot depend entirely upon the porosity of the molding sands, but must provide channels or *vents* for the escape of these gases.

For light work a free use of the vent wire through the sand in the cope will answer all purposes.

On castings of medium weight, besides venting with the wire, risers are placed directly on the casting or just off to one side as shown in Figs. 19 and 21. These are left open when the mold is poured and provide mainly for the escape of the air from the mold.

Heavy castings that will take some time to cool, and thus keep facings burning for a long time after the mold is poured, require venting on sides and bottom as well as top. Fig. 21 shows side vents *a a* *a a* connecting with the air through the channel *b b b* cut along joint and risers *c c c* passing through the cope. At the bottom the vents connect with cross vents *d d* run from side to side between the bottom board and edge of flask. Fig. 22 shows a mold bedded in the floor; the side or down vents connect at the top, as in previous examples, and at the bottom with a cinder bed about 2 inches thick, rammed over entire bottom of pit. The gases find escape from this cinder bed through a large gas pipe.

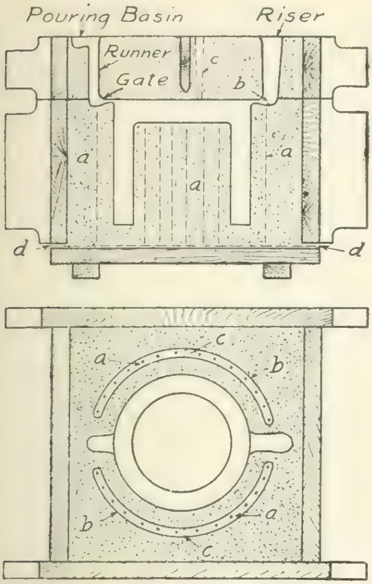


Fig. 21. Use of Risers.

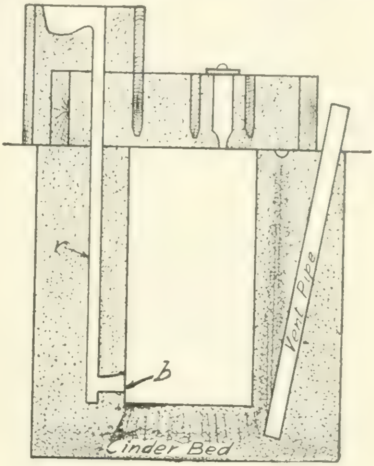


Fig. 22. Mold Bedded in Floor.

In pouring, the gas from vents should be lighted as soon as may be. The burning at the mouth of vents helps draw the gases from below and also keeps the poisonous gas out of the shop.

It is customary to keep risers closed with small cover plates when large castings are being poured so that the air in the mold will be compressed as the metal rises in the mold. This helps sustain the walls of the mold and forces the vents clear so that they will act more quickly when the mold is full. These covers are removed occasionally to watch the progress of pouring, and are entirely removed when the metal enters the risers.

GATING

Gating is the term applied to the methods of forming openings and channels in the sand by which liquid metal may enter the mold cavity. The terms *sprues* and *runners* are also used with the same meaning in some shops.

There are practically three parts to all gates—the pouring basin, the runner, and the gate. See Fig. 21. The runner is formed by a wooden gate plug made for the purpose. The pouring basin is shaped by hand on top of the cope, and the gate proper is cut along the joint surface by means of a gate cutter. In all cases the gate section should be smaller than any other part so that, when pouring, the runner and basin may be quickly flooded; also that the gate when cold will break off close to the casting and lessen the work of cleaning.

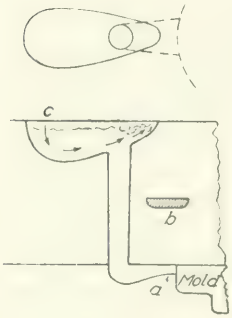


Fig. 23. Gate.

The object of gating is to fill the mold cavity with clean metal—to fill it quickly, and while filling, to create as little disturbance as possible in the metal.

The impurities in liquid metal are lighter than the metal itself, and they always rise to the top when the melted metal is at rest or nearly so. Advantage is taken of this important property to accomplish the first of the objects mentioned.

Fig. 23 shows a good type of gate to use on light work. For reasons given, the point *a* should have the smallest sectional area. This section should be wider than it is deep as shown at *b*, because the hot iron necessary for light work runs very fluid.

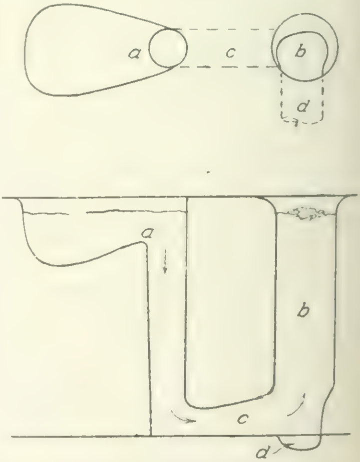


Fig. 24. Skimming Gate.

The runner should not be more than $\frac{5}{8}$ to $\frac{3}{4}$ inch in diameter. The pouring basin should be made deepest at point *c*, and slant upward crossing the runner. When pouring, the stream from the ladle should enter at *c*, flood the basin at once, and keep it in this condition. The current of the metal will then tend to hold back the slag, allowing clean metal to flow down the runner.

When particularly clean castings of medium weight are required, some form of skimming gate should be used. Fig. 24 illustrates one of several practical forms. They all depend for their efficiency upon the principle cited above. In the cut, *a* is the pouring basin and runner, *b* is a good sized riser placed about 3 or 4 inches from *a*, and *c* is a channel cut in the *cope joint*, connecting these two. The gate *d* should be cut in the drag side of the joint, just under the riser but at an angle of 90° or less with *c*. The metal rushing down the runner is checked by the small size of the gate and so washes any dirt or slag up into the large riser *b*. The level of metal in this riser must be sustained by sufficiently rapid pouring until the mold is filled.

In bench work and floor work, the greatest care must be used to have all parts of the gate absolutely free from loose sand or facing which will wash into the mold with the first flood of metal.

On heavy work special skimming gates are not used, for the capacity of the pouring basin is very much greater than that of the runners which can be quickly flooded and thus retain the slag. Besides this, large risers are set at the sides or directly upon the casting, to receive any loose sand or facing that washes up as the mold is being filled. Fig. 22 illustrates this type.

In regard to filling the mold quickly and quietly, the two are closely allied. The shape and thickness of the casting are the important factors in determining the number and position of the gates. Aside from the fact that the gate should never be heavier than the part of the casting to which it attaches, the actual size of the gate opening is something that the molder must learn from experience.

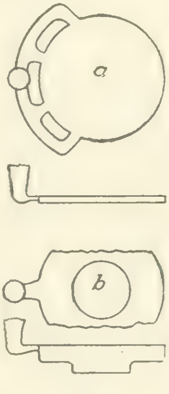


Fig. 25.
Use of Gates.

In arranging gates with regard to the shape of the pattern, the following points should be borne in mind. Place gates where the natural flow of the metal will tend to fill the mold quickly. Usually gate on lighter sections of casting. Select such points on the casting that the gates may be broken and ground off with least trouble. The greater the number of castings to be handled, the more important this point becomes. A study of the molding problems given will illustrate this point.

Provide enough gates to fill all parts of the mold with metal of uniform temperature. This depends upon the thickness of the work, as is illustrated in Fig. 25, by two molds having same shape at joints, but different thicknesses. In thin castings the metal tends to chill quickly, so it must be well distributed. In the cut, *a* is a plate ¼ inch thick, and should have several gates. A piece having the same diameter but heavier, would run better from one gate, see *b*, while if a bushing of this diameter is required, the best results would be obtained by gating near the bottom, as in Fig. 22. For running work at the bottom as shown in Fig. 22, the gate piece *b* is separate from the runner, and is picked into the mold after the pattern is drawn. The runner *r* should extend below the level of the gate to receive the force of the first fall of metal, which otherwise would tend to cut the sand of the gate.

SHRINKAGE HEADS

Melted metal shrinks as it cools, and this process begins from the moment the mold is filled. The surfaces next to the damp sand are the first to solidify, and they draw to themselves the more fluid metal from the interior. This process goes on until the whole casting has solidified. This shrinkage causes the grain in the middle to be coarse and sometimes even open or porous.

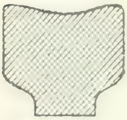


Fig. 26.
Sinking of Casting.

The lower parts of a casting are under the pressure or weight of all the metal above, and so resist these shrinkage strains. The top parts, however, require the pressure of liquid metal in gates or risers to sustain them until they have hardened sufficiently to hold their shape, or they will sink as indicated by the section, Fig. 26. *Risers* mentioned in connection with securing clean metal are also required on heavy pieces to prevent this distortion and give sound metal. When used in this way they are called shrinkage heads or feeders. They should be 6 or 8 inches in diameter, so as to keep the iron liquid as long as possible, and should have a neck 2 or 3 inches in diameter, to reduce the labor required to break them from the casting in cleaning. To prevent the metal in this neck from freezing, an iron feeding rod is inserted, as in Fig. 27, and churned slowly up and down. This insures fluid metal reaching the interior. As the level in the feeder lowers, hot metal should be added from a hand ladle.

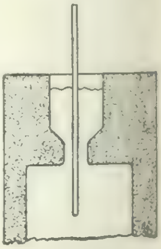


Fig. 27.
Feeding Rod.

PRESSURE IN MOLDS

The subject of the pressure of liquid iron mentioned repeatedly in the foregoing pages, must be dealt with by the molder in weighting his copes, strengthening flasks, securing cores, etc., but most frequently by the first of these.

Molten iron acts in accordance with the same natural laws that govern all liquids—as for example, water (see Mechanics, Part II). Iron, however, is 7.2 times heavier than water. The two laws applicable in foundry work are these: Liquids always seek their own level: Pressure in liquids is exerted in every direction.

Applying these laws: If we have two columns of liquid iron connected at the bottom, they would just balance each other. For convenience we shall leave out of our calculations the upward pressure on the gates in the following examples, for in practical work they need seldom be taken into account.

In A, Fig. 28, suppose these columns stand 6 inches above the joint *b d*, and that column *c d*, has an area of 1 sq. in. In B, suppose the area of the right hand column *c d e f* is five times the area of column *c d*. In both cases the level with top of runner *a* will be maintained. The depth of the cavity below the joint *b d f* makes no difference in maintaining these levels. The weight of one cubic inch of iron, .26 lb., is taken as the basis of all calculations.

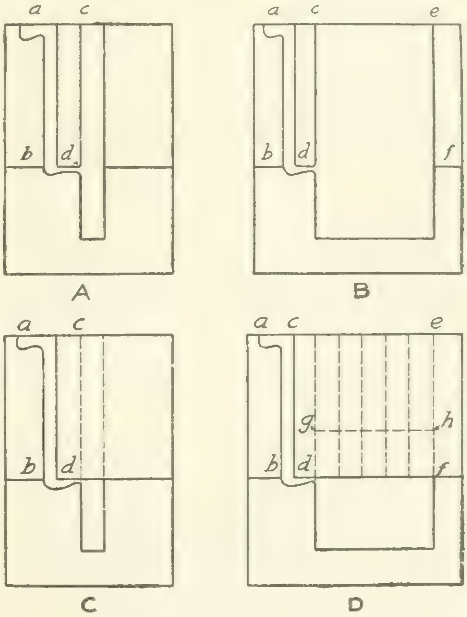


Fig 28. Pressure of Liquids.

Now if we close the column *c d* at *d*, as in C, it is clear that it would require the actual weight of that column to balance the lifting pressure on surface *d*, or 6 inches × .26 × 1 sq. in = 1.56 lbs. And if the larger area *d f* is closed over, as in D, it takes five times this weight to resist the pressure exerted upon it by the runner, or 6 inches × .26 × 5 sq. in. = 7.8 lbs. If the pattern projected 2 inches into the cope the height of the runner above the surface acting against the cope would be but 4 inches, and the pressure to be overcome would be equal to the weight of *c d g h*, equal to 4 inches × .26 × 5 inches = 5.2 lbs.

The important factors are, then, *height of runner*, and *area of mold which presses against the cope.* We can therefore state a rule: To calculate the upward pressure of molten iron, multiply the depth in inches by the weight of one cubic inch of iron (.26) and this product by the area in square inches upon which the pressure acts.

Applying the second law cited, the strains on sides and bottom of molds and upon cores is explained.

By the rule we first find the pressure per sq. in. at any given level by multiplying the depth by .26, and it is obvious that this pressure increases the lower in the mold a point is taken.

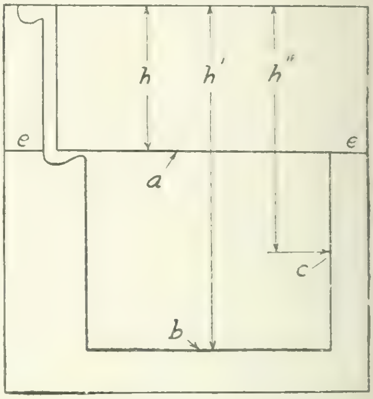


Fig. 29. Pressure of Liquids.

In Fig. 29, the pressure at *a* equals *h* × .26. This also acts against the sides at *e e*. The pressure at *b* is *h'* × .26, and is exerted sidewise and downward. The pressure at *c* is *h"* × .26. This point being half way between levels *a* and *b*, represents the average sidewise or lateral pressure on all of the sides.

If this mold then is 11 inches square, and 9 inches deep, with the pouring basin 6 inches above the joint, we have

Area of *a*, 121 sq. in.
Area of *b*, 121 sq. in.
Area of *c*, (one side), 99 sq. in.
Area of four sides, 396 sq. in.
Height of *h* = 6 in. = 1.56 lbs. per sq. in. in pressure.
Height of *h'* = 15 in. = 3.90 " " " " " "
Height of *h"* = 10½ in. = 2.73 " " " " " "

Multiplying these together, we have

Upward pressure on a = 188.76
Total pressure on side c = 270.27
Total pressure on four sides = 1081.08
Total downward pressure on b = 471.90

A study of these figures shows the necessity of well made flasks and bottom boards, for these must resist a greater pressure even than that required to keep the cope from lifting. They also show clearly why the lower parts of the casting will resist the pressure of the gases more and require firmer ramming than the upper portions.

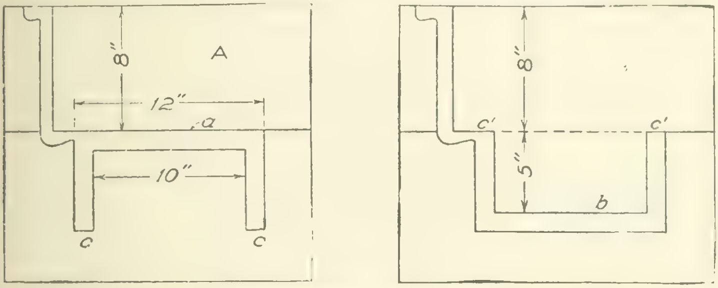


Fig. 30. Pressure of Liquids.

A difference in the way a pattern is molded may make a great difference in the weight required on the cope. Compare A and B, Fig. 30. Suppose this pattern is cylindrical in shape, we would have

Area of circle a (from table),—113.10
Area of circle b (" "), — 78.54
Area of ring c' c', equal to b subtracted from a, or 34.56.

Then:

Total lift on cope A is $8 \times .26 \times 113.10 = 235.24$ lbs.
The lift on cope B is $8 \times .26 \times 34.56 = 71.88$ lbs.
and $(8 + 5) \times .26 \times 78.54 = 265.46$

making a total of ....337.34 lbs. on B.

Fig. 31 is an example of a core 5 inches square surrounded by 1 inch of metal, with a runner 6 inches high; we have here,

Pressure per square inch on a is $7 \times .26$ or 1.82 lbs.
" " " " " b " $12 \times .26$ or 3.12 "

The difference in these pressures is 1.30 lbs. per sq. in. Then for every foot of length in the core we must balance a lifting pressure on the bottom of the core of 5 inches × 12 inches × 3.12, or 187.2 lbs. until the metal covers surface *a*, when it will exert a counteracting downward pressure, and the strain on the chaplets will be only 60 × 1.30 lbs. or 78 lbs.

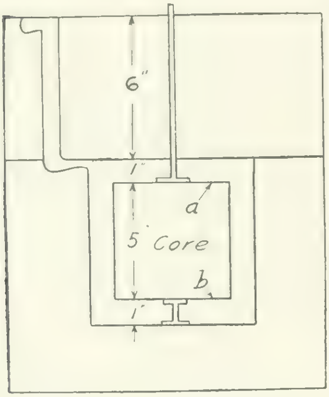


Fig. 31. Pressure of Liquids.

Some of the ordinary defects which the beginner will find on his castings are as follows:

Poured Short: The amount of metal in the ladle is misjudged with the result that the mold is not completely filled.

Blow holes come from gases becoming pocketed in the metal instead of passing off through the sand. This is due to hard ramming, wet sand, etc.

Cold Shuts form when two streams of metal chill so much before they meet, that their surfaces will not fuse when forced against each other; see Fig. 32.

Sand Holes come from loose sand or excess of facing washing into the mold cavity when pouring. They are usually bedded in the cope side of casting.

Fig. 32. Cold Shuts

Scabs show like small warts or projections on the surface of the casting. They result from small patches of the mold face washing off. They may be caused from too much slicking, which draws the moisture to the surface of the mold, making the skin flake under the drying effect of the incoming metal.

Swells are bulged places on a casting due to soft ramming. This saves the walls of the mold too soft to withstand the pressure of the liquid metal.

Shrinkage Cracks are due to unequal cooling in the casting. They are sometimes caused by the mold being so firm that it resists the natural shrinkage of the iron, causing the metal to pull apart when only partially cold.

Warping occurs when these strains cause the casting to bend or twist, but are not sufficient to actually crack the metal.

TYPICAL MOLDING PROBLEMS

When starting to ram up a flask see that the sands to be used are well cut through and properly tempered. Select a flask large enough to hold the pattern and have at least 2 inches clear of the flask all around for bench work, and 4 to 8 inches on floor molds, depending upon the weight of the work to be cast. See that the flask is strong enough to carry the sand without racking and that the pins fit. Have the necessary tools at hand, such as sieve, rammer, slicks, etc.

Examine the pattern to be molded to see how it is drafted and note especially how the parting line runs. That part of the mold forming the surface between the parts of the flask is called the joint and where it touches the pattern this joint must be made to correspond with the parting line.

The joint of a mold will be a plane or flat surface, or it will be an irregular one. When the joint is a *flat surface* it is formed entirely by the mold board except with work bedded in the floor; there it is struck off level with a straight edge. When it is *irregular* the drag joint must be "coped out" for every mold needed; that is, shaped free hand by the molder before making up the cope; or the shape of the *cope* joint is built up *first* in a "match" frame with the cope part of the pattern bedded into it. Upon this form the drag may be packed repeatedly, receiving each time the desired joint surface without further work on the molder's part.

Our first problems in molding will illustrate these three methods of making the joint.

It is aimed to give the directions for making up molds in as concise a form as possible. The student should refer frequently to the preceding sections and familiarize himself with the reasons underlying each operation.

To make a mold having a flat joint. In the small face plate shown in Fig. 33, all of the parting line *a a a* will touch the mold board, so the joint will be flat. The draft is all in one direction from the cope side *c*, therefore all of the pattern will be in the drag. Use a snap flask for this piece.

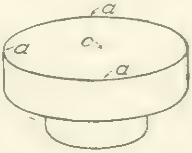


Fig. 33. Face Plate

Place a smooth mold board upon the bench or brackets. Place drag with sockets down upon this. Set pattern a little to one side of the center to allow for runner. Sift sand over this about $1\frac{1}{2}$ inches deep. Tuck sand firmly around the pattern and edges of flask as indicated by arrows, Fig. 34, using fingers of both hands and being careful not to shift sand away from pattern at one point when tucking at another.

Fill the drag level full with well cut sand. With the peen end of the rammer slanted in the direction of the blows ram first around the sides of the flask to ensure the sand hanging in well, see Fig. 35, 1-2. Next carefully direct the rammer around the pattern, 3-4-5. Do not strike closer than 1 inch to the pattern with the end of the rammer.

Shifting the rammer to a vertical position, ram back and forth across the flask in both directions, being especially careful not to strike the pattern nor to ram too hard immediately over it. The student must judge by feeling when this course is properly rammed. Now fill drag heaping full of sand. Use the butt end of rammer around edges of flask first, then work in toward the middle until the sand is packed smooth over the top. With a straight-edge strike off surplus sand to a level with the bottom of flask. Take a handful of sand and throw an even layer about ¼ inch deep over bottom of mold. On to this loose sand press the bottom board, rubbing it slightly back and forth to make it set well. With a hand at each end, grip the board firmly to the drag and roll it over. Remove the mold board and slick over the joint surface with the trowel. Dust parting sand over this joint (burnt core sand is good on this work), but blow it carefully off of the exposed part of the pattern. Set the wooden runner or gate plug about 2 inches from the pattern, as shown in Fig. 23.

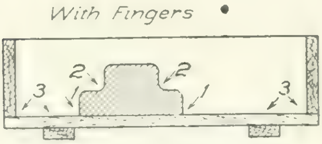


Fig. 34. Making a Mold.

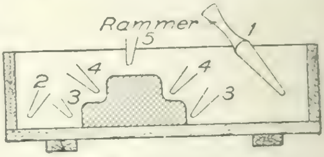


Fig. 35. Making a Mold.

In snap work the runner should come as near the middle as possible, to lessen the danger of breaking the sides, and to allow the weight to be placed square on top of the mold.

Set the cope on the drag and see that the hinges come at the same corner.

Sift on a layer of sand about 1½ inches deep. Tuck firmly with the fingers about the lower end of the runner and around the edges of the flask. Fill the cope and proceed with the ramming the same as for the drag.

Strike off the surplus sand, swinging the striking stick around the runner so as to leave a fair flat surface of sand. Drive the vent wire into the cope sand, making it strike the pattern a dozen times or more. Partially shape a pouring basin, illustrated in Fig. 23, with a gate cutter, before removing the runner. Draw the runner and finish the basin with a gate cutter and smooth it up with the fingers. Moisten the edges with a swab and blow it out clean with the bellows.

Lift the cope and repair any imperfections on the mold surface with trowel or slicks. See that the sand is firm around the lower end of the runner. Blow through the runner and all over the joint to remove all loose parting sand. Slick over the sand which will form the top surface of the gate, between the runner and the mold.

Having finished the cope, moisten the sand about the edges of the pattern with a swab. Drive a draw spike into the center of the pattern and with a mallet or light iron rod, rap the draw spike slightly front and back and crosswise. Continuing a gentle tapping of the spike, pull the pattern from the sand. If any slight break occurs, repair it with bench lifter or other convenient slick. Cut the gate and smooth it down gently with the finger; blow the mold out clean with bellows. Dust on graphite facing if castings are to be cleaned in rattler. No facing is needed if they are to be picketed. The mold should now be closed and the snap flask removed.

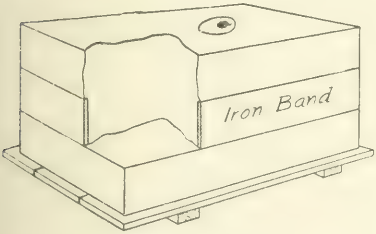


Fig. 36. Use of Iron Band.

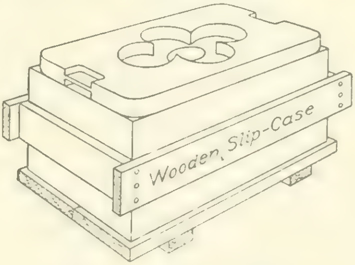


Fig. 37. Weight in Position.

There are two methods used to strengthen these molds against the casting pressure. One is to use an iron band which will just slip *inside* of the flask before the mold is packed. See Fig. 36. The other is to slide a wooden "slip case" over the mold after the snap flask is removed. See Fig. 37. In either case the weight, shown in position in Fig. 37, should not be placed on the mold until pouring time, lest by its continued pressure it might crush the sand.

A mold requiring to be coped out. The second type of joint surface mentioned above is illustrated by the method of molding the tail stock clamp shown in Fig. 38. This is a solid pattern and rests firmly upon the mold board on the edges *a a*, but the parting line *b b b* runs below these edges. The bulk of the pattern drafts down from this line, so will be molded in the drag while all above it will be shaped in the cope.

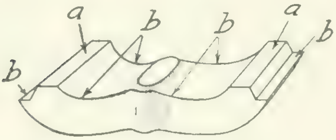


Fig. 38. Tail Stock Joint.

To mold the piece, set the pattern on the mold board planning to gate into one end. Ram the drag and roll it over as described in the last example. With the blade of the trowel turned up edgewise, scrape away the sand to the depth of the parting line, bringing the bevel up to the main level of the joint, about $2\frac{1}{2}$ inches from the pattern, as shown at Fig. 39. Slick this surface smooth with the finishing trowel or leaf and spoon. This process is called coping out. Dust parting sand on the joint thus made. Be careful not to get too much at the bottom of the coping next the pattern. Pack cope, then lift same, and finish mold as directed.

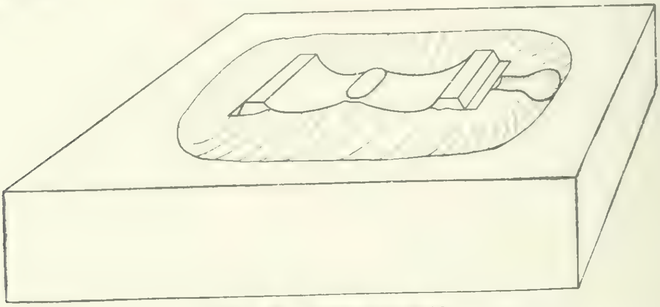


Fig. 39. Coped out Mold.

In coping out, the molder practically shapes draft on the sand of the drag. Aim to have the lower edge of the coping parallel with main joint for a short distance, and then spring gradually up to it at about the angle shown in the section, Fig. 40, at *c*, as this is the strongest shape for the sand.

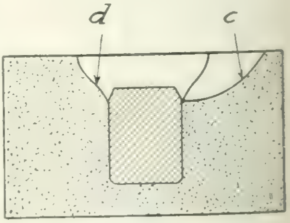
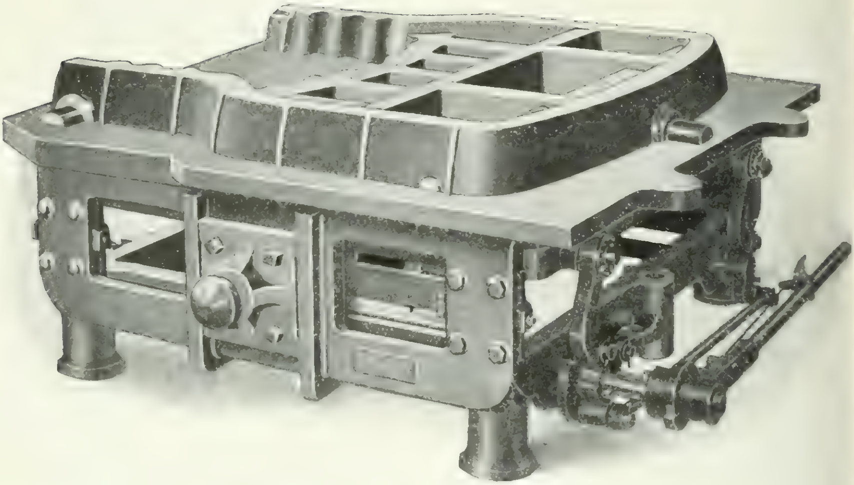


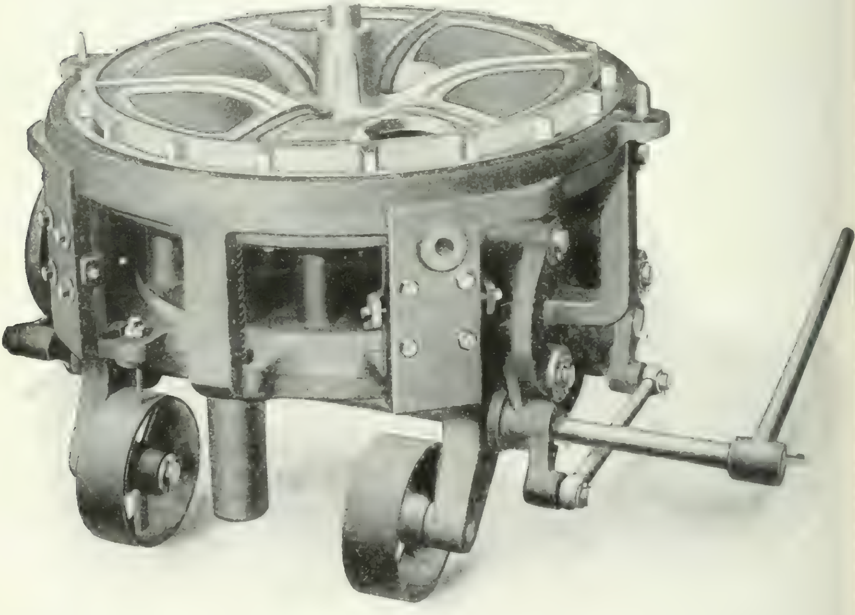
Fig. 40. Angle of Joint.

If made with an abrupt angle as in *d*, the cope sand will tend to



SQUARE MOULDING MACHINE

For Moulding Boiler Sections.



ROUND MOULDING MACHINE

For Making Wheels.

Henry E. Pridmore.

wedge into the cut with the danger of a "drop" or break when the cope is lifted.

In many cases, more especially in floor work, an abrupt coping angle may be avoided as follows: Set wooden strips, whose thickness is equal to the depth of the desired coping, under the edges of the drag when ramming up the pattern. (Use, for example, the hand wheel shown in Pattern Making, page 58). When the drag is rolled over the sand will be level with the top of strips and pattern at *a a*, Fig. 41. Remove the strips and strike surplus sand off level with edges of drag, *b b*, and slick off the joint. Proceed with the cope in the usual manner. In gating this pattern, and wheels generally, place a small runner directly on the hub.

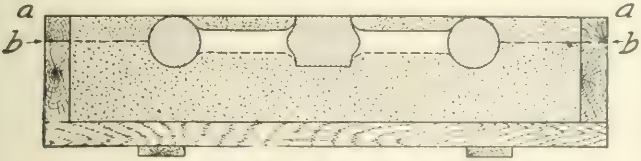


Fig. 41. Molding a Hand Wheel.

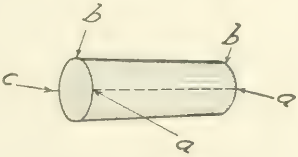


Fig. 42. Solid Bushing.

Using a sand match. The solid bushing, Fig. 42, will serve to illustrate the use of a sand match. For exercise work use only one pattern.

In practice, however, several small patterns are bedded into the same match. It is clear that in this pattern the parting line runs along the center of the cylinder, and to make a safe lift for the cope it should follow around the circumference of the ends from *a* to *c*, as shown by the heavy lines.

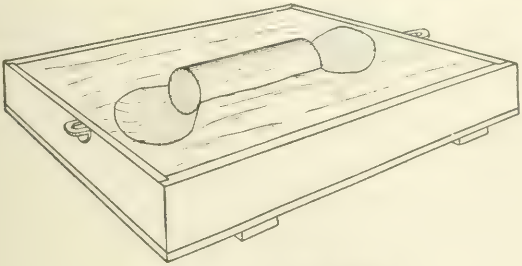


Fig. 43. Use of Sand Match.

The frame for the match is shallow, and of the same size as the snap flask with which it is used. It is provided with sockets to engage the pins of the flask. The bottom board is fastened on with screws.

Fill the match with sifted sand rammed hard. Strike off a flat joint and bed in the pattern. Cope out the ends to the lower edge of the pattern, as shown in Fig. 43, flaring it well in order to make a good lift. Slick the whole surface over smooth. Rap and lift the pattern to test the correctness of the work.

Replace the pattern. Dust on parting sand and ram drag, tucking carefully in the pocket at each end. Roll the two over. Lift off the match, and set it to one side. The pattern will remain in the drag. Dust on parting sand. Set the runner and ram cope as described. When the mold is opened and the pattern drawn, it should be set back immediately into the match, ready for use again.

On account of economy of construction in the pattern shop, irregular shaped work is often made in one piece. The molder mus then decide whether it is cheaper to cope out each joint or make up a sand match. Where the number of castings required is small, or where the pattern is large, it is better to cope out. But where a number of castings is required it is cheaper to make up a sand match.

For methods of making quantities of castings and use of a mor permanent match, see section on Duplicating Castings.

In the foregoing the main use of the match was to save time. I frequently happens that a pattern is so irregular in shape that it wil not lie flat on the board in any position. In this case a match is absolutely necessary before the drag can be packed. For large pattern of this kind, the cope box of the flask is used to bed the pattern int instead of a separate frame. After the drag has been packed upon i this first cope is dumped, and the box repacked with the necessar gaggers, vents, runners, etc., required for casting. The first cope i then termed, not a match, but a *false cope.*

For very light wooden patterns which may or may not have ir regular parting lines, the pattern maker builds up wooden forms t support the thin wood while the drag is being packed and to give th proper joint surface to the sand. This board serves exactly the sam purpose as the sand match and false cope, but it is termed a *follo board.* See Pattern Making, page 137.

So far the patterns used have been made in one piece, but a fla joint is the most economical for the molder, when many castings are required. Generally such pieces as bushings, pipe connections and symmetrical machine parts are made in halves; one piece of the pattern remaining in each part of the flask when the mold is separated. There are many cases, too, where, to make a flat joint for the mold, the pattern maker can separate one or more projections so as to have the main part of the pattern in the drag and let these loose parts lift off in the cope.

The small punch frame and the gas engine piston, shown in Fig. 44, are examples of these two classes of patterns. At A, the section through the patterns shows the methods of matching them together.

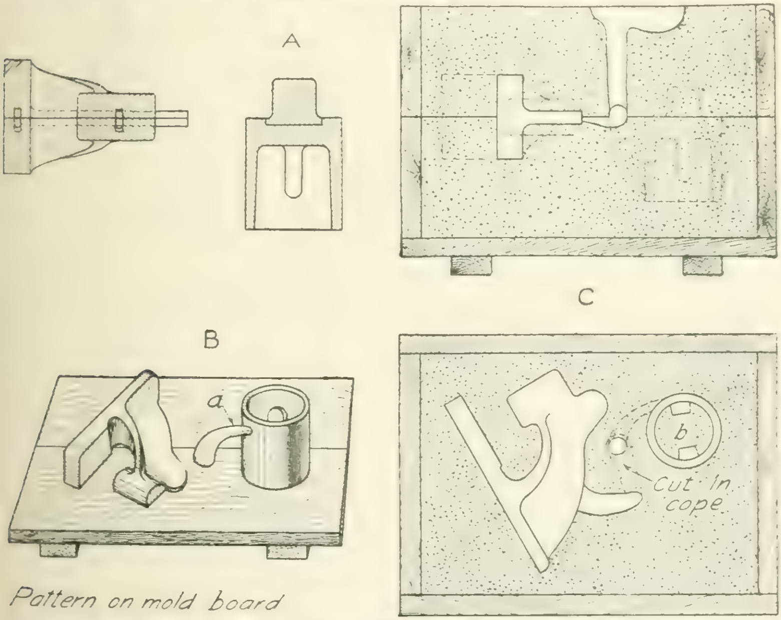


Fig. 44. Split and Loose-Piece Patterns.

B shows the drag parts of the patterns in position for molding. At C is the section through the mold and the plan of the drag showing how the gates are connected. Attention is directed to the use of the *horn sprue*—the sprue pattern is shown at *a*—by which the metal enters the mold at the bottom. If the gate were cut at the joint surface there would be danger of "cutting the sand" on top of the green sand core *b* as the metal flowed in upon it.

Some work has projections on it which lie above or below the parting line in such a way that it cannot be molded by either of the foregoing methods.

Examining the patterns for some of this work we find two entire parting lines with the pattern made to separate between the two. Such patterns require between the drag and cope an intermediate body of sand, from the top and bottom of which the two parts of the pattern may be drawn.

In small work, as illustrated by the groove pulley, this intermediate form is held in place by the sand joint of the cope and drag, and is termed a *green sand core*. A good description of the method of molding such a piece is given in Pattern Making Part I, page 60. To provide for pouring the casting a runner should be placed on the hub of the first part packed, C. Fig. 45 shows a section of the mold before either part of the pattern has been removed. Now, when the flask is rolled over to remove the final part C of the pattern, the runner is on top ready for pouring.

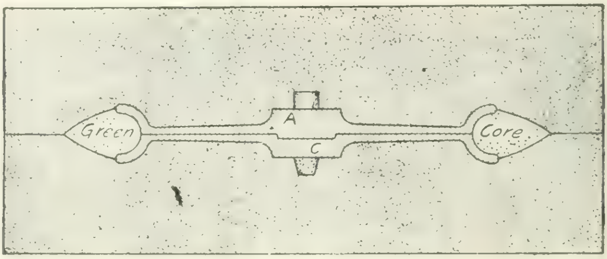


Fig. 45. Section of Mold.

Another method used does away with rolling the entire flask. A core lifting ring is first cast slightly larger in diameter than the flange of the sheave, and having a section shown in *a*, Fig. 46. The ring is set in position in the middle of the inverted *drag*, the pattern is held central inside of the ring by the recess in the mold board. Pack the drag, roll over, and remove the mold board. Tuck the green core all around and slick off the top joint of the core. Pack the cope in the usual way, lift it off, and draw the cope pattern. Now, by means of lugs cast on this lifting ring, the green core may be lifted off

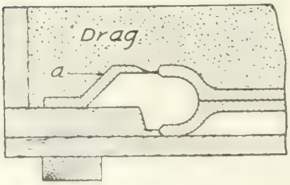


Fig. 46.

of the drag pattern, allowing it to be removed. Replace the ring, close the cope, and the mold is complete. See half-section, Fig. 47.

In larger work, where the parting planes are farther apart, this intermediate body of sand is carried in a "cheek" part to the flask, and we speak of it as three-part work.

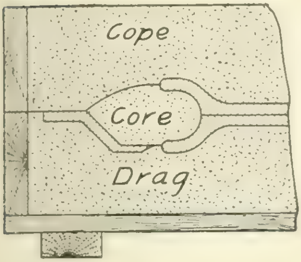


Fig. 47.

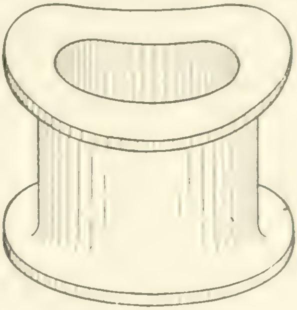


Fig. 48.

Fig. 48 shows a casting for a 10-inch nozzle, the mold for which illustrates this class of work. Here the pattern is separated just above the fillet of the curved flange. Fig. 49 gives a view of the mold, showing the way the joint is formed.

This casting should be made on the floor. Select a square flask 4 inches on a side, larger than the diameter of the flanges. The cheek should be as high as that part of the pattern which is molded in it. There should be two projecting bars on opposite sides of the cheek to support the sand, and crossbars in both drag and cope. These should be well wet with clay wash before using the boxes.

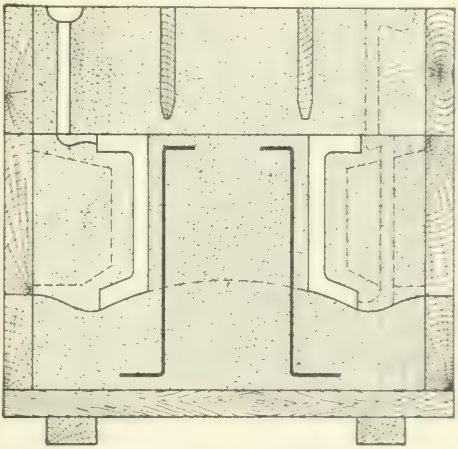


Fig. 49. Casting a Nozzle.

Set the pattern centrally inside the cheek, and place a runner stick just the height of the pattern in one corner of this box.

On account of the depth of the cheek the sand must be rammed in two courses. Sift enough facing sand into the box to cover the joint and 5 inches up around the pattern to a depth of about $1\frac{1}{4}$ inches, tucking about the pattern with the fingers. Fill in about 5 inches of loose sand and before ramming tuck around the ends of the side bars, compressing the sand between the finger tips, having a hand on each side of the bar, as illustrated in Fig. 50. Now use the peen end of the floor rammer in the same general way as the hand rammer is used in bench molding. Guide the rammer around the sides of flask and bars first, then direct it toward the bottom edges of pattern. As the sand gradually feels properly packed at this level, direct the blows higher and higher up. Proceed in this way to within about 1 inch of the drag joint. Make this joint by ramming in sifted facing sand, being careful to tuck it firmly underneath the flange. Cope this joint to the shape of the curved flange.

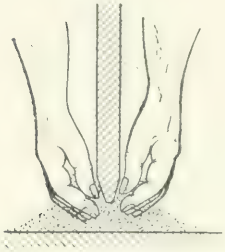


Fig. 50.

Dust on parting sand. Place the drag in position and ram it up in the usual way, only using facing sand next the joint and pattern. Place six long gaggers to strengthen the sand which forms the inside of the casting. Clamp drag to cheek and roll them over Test, repair and sand the joint. Try the cope. The bars should clear the pattern and joint by about 1 inch. Set the cope runner about 2 inches to one side of the cheek runner and set the riser in the corner opposite. Sift on facing sand and tuck well with the fingers under the crossbars. Shovel in well-cut sand and finish packing the cope. Form a pouring basin, and vent well. Lift the cope. Draw the pattern from the cheek. Join the runners on the cope joint and connect the mold with the riser. Lift the cheek and repair it. Draw the drag pattern. All of the mold surfaces should have black lead facing brushed over them with a camel's hair brush, and this facing slicked over with convenient

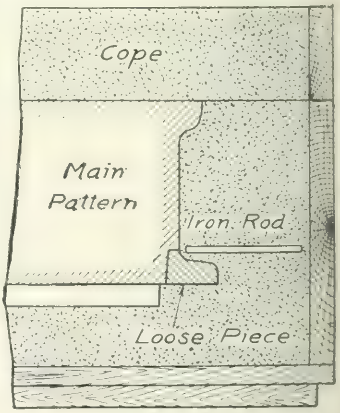


Fig. 51.

tools. Cut a gate on the drag joint. Close the cheek on the drag. Close the cope on the cheek and the mold is ready for clamping.

It often happens that bosses or projections are required on a casting at right angles to the main draft lines of the pattern and below the joint surface. Examples of such cases are shown in Pattern Making, pages 61–116. In molding such work, care must be taken that the overhanging portion of sand shall be strong enough to support itself. Where the projection is deep, the mold should be strengthened by nails or rods as shown in Fig. 51. These should be wet with clay wash and set into the sand, when the mold is rammed.

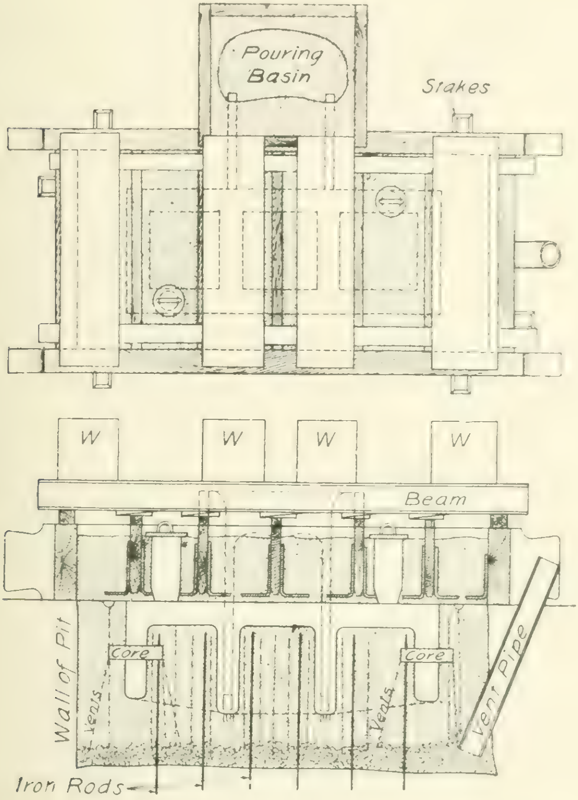


Fig. 52. Casting a Flask Section.

Owing to the development of the electric crane, much large work is now rammed in iron flasks and rolled over, which was formerly always bedded in the floor. This method is still much used in jobbing shops to avoid making a complete large flask.

The mold shown in Fig. 52 will illustrate the principal operations involved. The casting is a flask section for a special steel ingot mold, and in design is simply a heavy plate braced on one side by flanges and ribs of equal thickness.

For convenience in ramming between the flanges, portions of the top plate of the pattern are left loose. See Fig. 53.

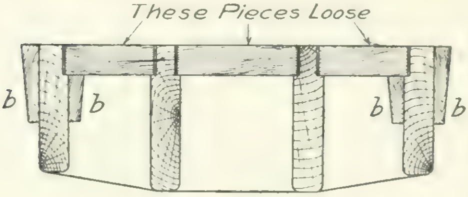


Fig. 53. Bedded-in Work.

Dig the pit for the mold 10 inches larger on each side than the pattern, and about 6 inches deeper. Having screened some hard cinders through a No. 2 riddle, cover the bottom of the pit with them to a depth of 3 inches. Ram these over with a butt rammer, and at one end set a piece of large gas pipe Put a piece of waste in the top of this to prevent its getting choked with sand. Ram a 3-inch course of sand over the cinder bed and strike it off level at the depth of the pattern from the floor line. Sift facing sand over this where the pattern will rest. Set the pattern, and with a sledge, seat it on this bed until it rests level. Remove the pattern and with the fingers test the firmness of packing all over its impression.

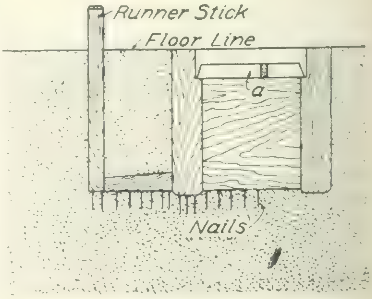


Fig. 54.

Vent these faces through to the cinder bed, and cover the vent holes with a $\frac{1}{2}$-inch course of facing sand. Now replace the pattern, and bed it home by a few more blows of the sledge. The top of the pattern should now be level and flush with the floor line. Seat the runner sticks, and to prevent the sand on the bottom of the runners from cutting, drive 10-penny nails about $\frac{3}{4}$ inch apart into this surface until the heads are flush. Ram the outside of the mold the same as if in a flask, and strike a joint on top. Ram green sand between the inside webs of pattern, and strike off at the proper height with a short stick *a*, Fig. 54. Drive long rods 3 inches apart into these piers to pass through to solid sand below the cinder bed.

Vent all around the pattern, outside and inside, through to the cinder bed. On top of the inside piers cover these vent holes with facing sand, ram and slick to finish; then cover with the loose pieces of the pattern.

Try the cope and stake it in place; set the risers and vent the plugs. Ram the cope, slicking off level for about 2 inches around the top of the risers, to receive a small iron cover.

Lift the cope, repair, and face with graphite. Draw the pattern with the crane and finish the mold. Connect the outer vent holes by a channel with the vent plug. From the end of each core print *a a a a* vent through to the cinder bed and set cores. Close the cope. Set the runner box against the side of the cope and build a pouring basin with its bottom level with the top of the risers.

In weighting, great care must be exercised not to strain the cope

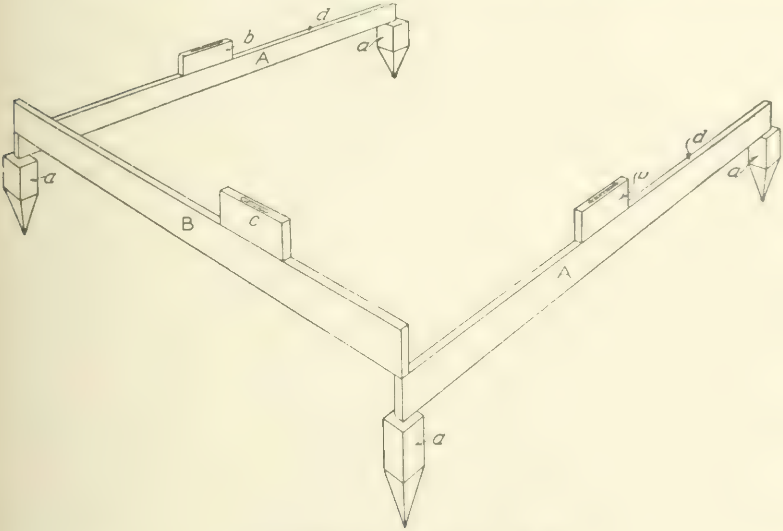


Fig. 55. Leveling a Bed for Open Sand Work.

Place blocking upon the top ends of cope. Across these lay iron beams which will be stiff enough to support the load, and pile weights on these. Now wedge under the beams to the crossbars of the cope at necessary points.

There is a large class of foundry rigging, such as loam plates, crossbars and sides to iron flasks, which may be cast in open molds. As there is no "head of metal" the beds must be rammed only hard enough to support the actual weight of the metal, or it will "boil." To insure uniform thickness in the casting, the bed must be absolutely level.

Drive four stakes, *a a a a*, and rest the guide boards A A on the top of these, as shown in Fig. 55. By using a spirit level *b b*, make these level and bring them to the same height by testing with the straight edge B.

The space between the guide boards A A should be filled with well-cut sand even with their tops *d d*. Sift sand over the entire surface. Strike this sand off ¾ inch higher than the guides, by placing a gagger under each end of the straight edge, as it is drawn over them. Tamp this extra sand to a level with the guides by rapping it down with the edge of the cross straight edge, and the bed will be as shown in Fig. 56. We can now proceed to build up to a segment of pattern, or with a sledge drive a pattern into this surface.

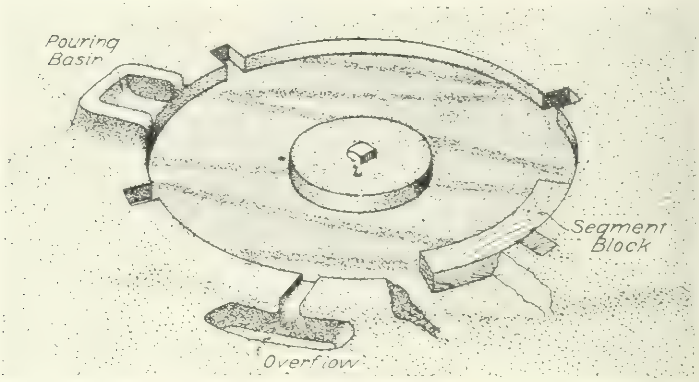


Fig. 56 Open Sand Mold.

The pouring basin should drain itself at the level of the top of mold, and an overflow may be cut on one edge to drain the casting to any desired thickness.

CORE MAKING

Reference has been made in the first part of this book to the general difference between core making and green sand work.

This, and the section on sands, the reader should review carefully.

Here, as in green sand molding, the principal material used is a refractory sand. In molding sand, however, the alumina or clay forms a natural bond in the sand. To meet the necessary requirements of cores we must use a naturally free sand as a base, and give it bond by adding some form of organic matter as a binder and then bake the core.

The most common binders are as follows:

Flour: Ordinary wheat flour is an almost universal material for this purpose. Every one is familiar with the action of this material when moistened and baked.

Rosin is a hard vegetable gum—a by-product of the manufacture of turpentine. For use as a core binder it should be reduced to a powder. It melts under the heat of the oven and flows between the grains of sand and upon cooling binds them firmly together.

Linseed Oil is made from flax seed. It acts in a way similar to rosin; a small proportion of oil together with some flour makes a very strong core.

Glue, obtained from animal hoofs, and from fish stock, is also used to some extent as a core binder. It should be dissolved in water before mixing with the sand.

A weak *molasses water* is used for tempering the sand for small cores, and *clay wash* serves the same purpose on the larger work.

There are many patent combinations of the above or similar materials put on the market as core compounds. There are two classes of these: dry and liquid compounds. The advantages claimed for them is that they are more economical, (1) because a smaller proportion of the compounds is sufficient to obtain the desired results; (2) because a large proportion of the sand may be used over and over again.

Other necessary core room supplies are:

Annealed Iron Wire, No. 6 to No. 16, and round bar iron in sizes of ¼ inch, ⅜ inch, ½ inch, ⅝ inch, ¾ inch. This material is cut to length as needed, and bedded in the core sand to strengthen the core, as will be demonstrated later.

A supply of clean *cinders* must be available for venting larger cores. Small wax tapers make good vents for crooked cores. There is also a patented wax vent for sale on the market.

As before stated, charcoal with some graphite is the principal *facing* material used on cores. It is always applied in liquid form by dipping the core or by using a flat brush having extra long bristles.

The general tools of the core room are similar to those already mentioned. A piece of iron rod very often replaces the regular rammer on account of the small size of the opening into which sand must be packed.

The trowel is the most common slick, because most of the surfaces which require slicking are flat ones formed by "striking off" after packing the box. Except in the largest work the entire face of the core is not slicked over, so a variety of small slicks is not needed.

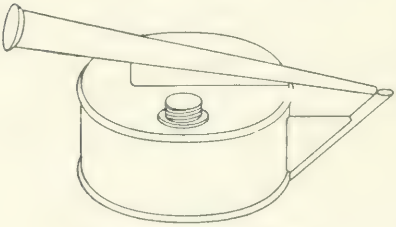


Fig. 57. Spraying Can.

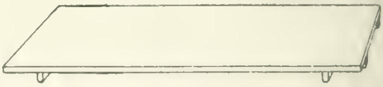
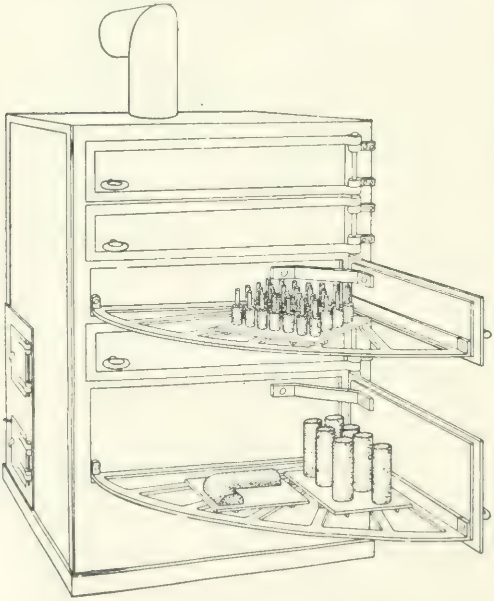


Fig. 58.

A spraying can, shown in Fig. 57, is used for spraying molasses water over small cores. Fill the can two-thirds full and blow into the mouthpiece.

Small cores are made up on a flat bench, the sand being in a small pile at the back. Larger boxes are rammed up on horses or on the floor, as is most convenient.



Fig, 59. Small Core Oven.

After being made up, cores are baked on core plates. The smaller plates are cast perfectly flat. Plates over 18 inches long are strengthened by ribs cast about **1** inch from the edge. See Fig. 58. This keeps the plate from warping and admits of its being picked up readily from a flat bench top or shelf.

Ovens are built with reference to the size of the cores to be baked. A good type of small oven is illustrated in Fig. 59. It can be run very economically with either coal or coke, and will bake cores up to 2 inches in diameter inside of half an hour. Each shelf is fastened to its own door and when open, for receiving or removing cores, a door at the back of the shelf closes the opening. This prevents a waste of heat.

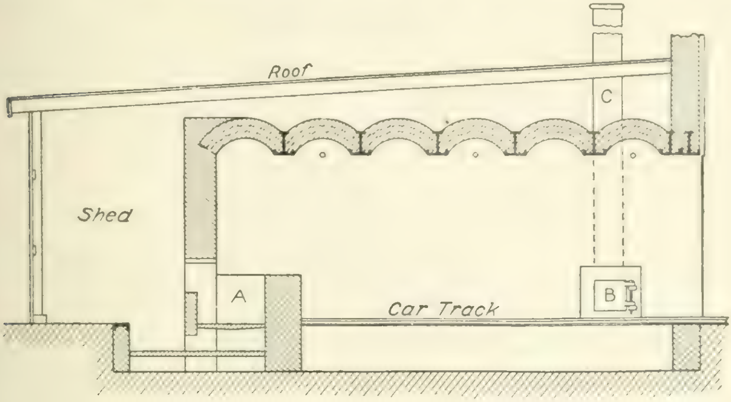


Fig. 60. Core Oven for Large Work.

Fig. 60 shows the section through an oven suitable for the largest work, including dry sand and loam molds. The fire box A is situated in one corner at the back; its whole top opens into the oven. At the floor level diagonally opposite is the flue B for conducting the waste heat to the stack C. The entire front of the oven may be opened by raising the sheet steel door. Two tracks side by side accommodate cars upon which heavy work is run into the oven. Fig. 61 shows a good form of cast-iron car. The wheels are designed on the roller principle to make it easier to start the car when heavily loaded.

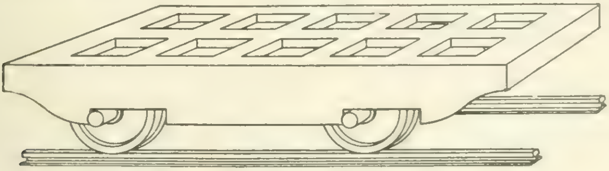


Fig. 61. Cast Iron Car.

For medium work smaller ovens of this type are used. Racks similar to the one shown in Fig. 62 may be bolted on the sides, arranged to hold the ends of the core plates; and the car may carry a line of double racks to increase the capacity of the oven.

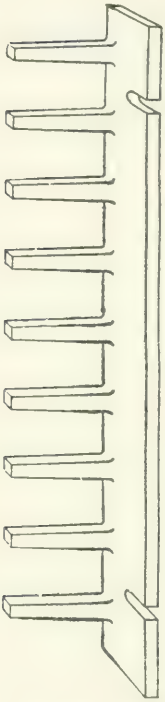


Fig. 62. Rack.

As mentioned before, cores form those parts of a mold which will be nearly or entirely surrounded by metal. In other words, such parts as would be in danger of breaking or require too much work to construct in green sand. The object then in making cores is to make a better casting and reduce costs.

Cores are held in position by means of core prints (See Pattern Making, page 56). The main weight of the core is supported by these prints and through them all vent must be taken off and all sand removed in cleaning. Therefore cores must be stronger than green sand because whether large or small, they must stand handling while being set and must not cut or break during pouring. They require greater porosity than green sand because their vent area is limited and their composition contains more gas forming material. Furthermore, cores must lose all their bond by the time the casting is cold, so that the sand may be easily removed no matter how small the available opening.

These conditions are obtained by using a coarse free sand and a binder. To give additional strength when necessary, iron wire, or rods, or cast-iron core arbors are bedded in the core. These serve the same purpose in a core that the flask does in green sand work.

The action of the binder enables the sand to retain its shape when the box is removed, and renders the core hard and strong when baked. In the mold the intense heat of the metal gradually burns out the organic matter or "binder," leaving the core without bond. In this condition the sand may readily be removed.

Too much binder tends to make the core sag out of shape before baking, and "blow" when metal strikes it, that is, give off more gas than the vents can carry away. With too little binder the sand will not bake hard, and will "cut" when the mold is poured.

No universal mixture for core sand can be given, as sands vary so much in different localities. The following mixtures illustrate approximate proportions:

For small cores:

Beach sand	10
Flour	1

Temper with molasses water.

For large cores:

Sharp fire sand	8
Strong loamy sand	2
Flour	1½

Temper with clay wash.

For intricate smaller cores:

Beach sand	15	Beach sand	15
Fire sand	15	Molding sand	5
Rosin	2	Flour	2
Flour	1	Oil	1

Temper with molasses water.

Blacking for Light Work. One cup of molasses to a pail of water. Into this work powdered charcoal until an even black coating is deposited upon the finger when dipped into the blacking and out again.

Heavy Blacking. Use about 2 parts charcoal and 1 graphite, and mix into thick clay wash.

The effectiveness of all binders, especially flour, depends upon their thorough mixing with the sand. The especial value of rosin and oil lies in the fact that by melting under the oven heat they form a more perfect bond with the sand.

Many intricate cores are now made with an oil mixture, without using rods or wires, which formerly were considered absolutely necessary for strength.

Such cores must be well supported when green, must be thoroughly baked, and handled with much care until they are cold.

In preparing core sand the different ingredients should be measured out, thoroughly mixed and while dry, sifted. Temper the mixture a little damper than molding sand. Too much moisture will make the sand stick to the box. Not enough will make it hard to work and give a crumbly surface if dried.

In finishing small cores they should be sprayed with weak molasses water while green, then well baked and removed from the oven. When cool enough to handle, they are dipped into the blacking; then put back in the oven until this facing has dried. For large cores the blacking is applied with a brush before baking.

All cores should be baked as soon as made, for air-drying causes the surface to crumble.

Cores must not be set in a mold while they are hot, or the mold will "sweat," that is, beads of moisture will form on the inside faces. This would make the mold "blow" when poured.

A core should be rammed evenly and somewhat harder than a mold. Too hard ramming will make the sand stick in the box, besides giving trouble in casting. Too light ramming makes a weak core.

From the very nature of cores, the matter of venting them is very important and often calls for much ingenuity on the part of the core maker.

For simple straight work a good sized vent wire is run through before the box is removed. Half cores have their vents cut in each half before pasting together. Cinders are rammed in the center of large cores connecting through the prints, with the mold vents. For crooked cores, wax vents are rammed in the center—the wax melts away into the sand when the cores are baked, leaving smooth even holes. This will be illustrated in one of the following examples.

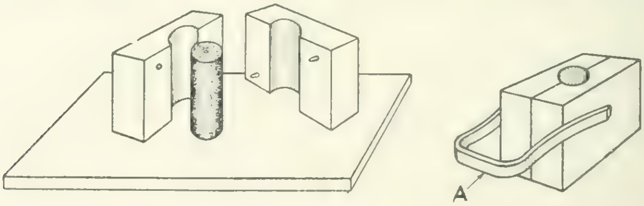


Fig. 63. Short Bolt-Hole Cores.

The examples here given will serve to illustrate the principal methods used in making cores.

The simplest form of core is one which can be rammed up and baked as made by simply removing the box. Short bolt-hole cores, etc., are made in this way, as shown in Fig. 63.

Set the box on a flat bench top. Hold the two halves together by the clamp A. Ram the hole full of core sand by use of a small rod.

Slick off the top; run a good size vent wire through the middle of the core. Remove the clamp. Set the box onto the core plate, rap the sides, and carefully draw them back from the core.

Larger cylindrical cores, up to about 1½ inches diameter, are rammed in a complete box also, only rolled out on their sides. See Fig. 64. This, however, tends to make a flat place on the side, from the weight of the sand supported on this narrow surface.

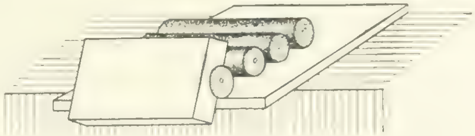


Fig. 64. Large Cylindrical Cores.

For this reason cylindrical cores of large diameter, and many symmetrical shapes, are made in half boxes. See Pattern Making, Figs. 111, 189, 194, and 200. Such boxes are rammed from the open side. Wires are bedded when necessary about in the middle of the half core. The fingers and handle of trowel are often used to ram the sand and with the blade of the trowel the sand is struck off and slicked to the level of the top of the box.

When baked, two half cores are held with their flat sides together, and any slight unevenness in the joint removed by a gentle rubbing motion. A vent channel is then scraped centrally on each half. Paste, made of flour and water, is applied around the edges and the two halves pressed firmly together; care is taken to see that they register all around. The core should then be placed in the oven to dry out the paste. When pasting cores of 6 inch diameter and over, it is well to bind the halves at each end with a single wrap of small wire.

Wherever possible, core boxes should be made with their widest opening exposed for packing the core, and designed so that the core may rest, while being baked, on the flat surface formed by striking off at this opening.

Core plates will sometimes become warped. When a core would be spoiled by resting it directly upon such a plate, the unevenness is overcome by sifting upon the plate a thin bed of molding sand and seating the core on this.

All cores cannot be made with a flat surface for baking, as illustrated by a port core, the box for which is shown in Pattern Making, Fig. 216.

This core must be rolled over on a bed of sand. Using an oil mixture, ram the core carefully, bedding into it several wax vents. These should start near the end which will touch the main cylinder core and lead out of the end which will enter the chest core. To get this crooked core on a plate for baking, a wooden frame is roughly nailed together, which is large enough to slip over the core box when the loose pieces have been drawn off of the core. See A, Fig. 65.

The space on top of the core is now filled with molding sand, rammed just enough to support the weight of the core. The edges of the frame project above the highest points of the core and form guides for striking off this sand and seating a core plate, as at B. Box, frame, and plate are now firmly clamped and rolled over, and the frame and box removed, leaving the core well bedded on the plate ready for the oven, as at C.

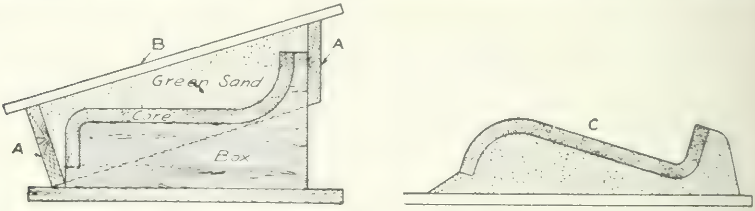


Fig. 65. Bedding a Crooked Core.

In manufacturing plants quantities of cores are often required which cannot be baked on a flat plate. To save the time and material necessary to roll each core onto a bed of sand, metal boxes are made, see Pattern Making, Figs. 227 and 228, and the core is baked in one part of the box. Only one casting is required of the larger portion of the box. The smaller part is duplicated for every core required for the day's molds.

Mention has been made of the use of wires for strengthening small cores. In making larger ones, there is a greater weight of sand to cause strain in handling the core, and proportionately greater casting strain. To resist these, a systematic network of rods is bedded in the core while being rammed, as shown in the sectional view, Fig. 66. Heavy bars *a a b b* extend the length of the core to give the main stiffness. Smaller cross rods rest on these at the bottom and top, and with the small vertical rods tie the whole core together.

At even distances from each end lifting hooks *c* are placed.

Cross rods through the lower eyes of these hooks bring all the strain of the lift on the long heavy core rods. The holes in the top of the cores where the lifting hooks are exposed, are stopped off when the core is in the mold, by moistening the sides of holes with oil and filling up with green sand.

Cinders are packed in the middles of such cores. They aid in drying the core. They furnish good vent, and they allow the sand to give when the casting shrinks, thus relieving the strain on the metal itself.

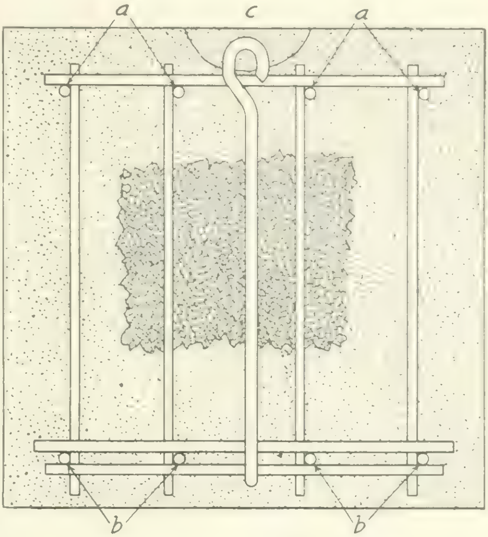


Fig. 66. Network of Rods in Core.

For the largest class of cores for green sand work, cast-iron "core arbors" are used. A very satisfactory type of arbor is shown in Fig. 67. This consists of a series of light rings A carried on a cast-iron beam B. The rings are of about ½-inch metal cast in open sand and set about 8 inches on centers, and may be wedged to the beam. The beam has a hole at each end for lifting the core.

This skeleton is made up and tried in the box before the work of ramming the core is begun. It is then removed and given a coat of thick clay wash. A layer of core sand is first lightly rammed over the inside of the box, and the core arbor seated into this. The full thickness of core sand facing is then firmly rammed, and the entire center filled with well packed cinders. Vents through the facing at both ends provide for the escape of gases from these cinders.

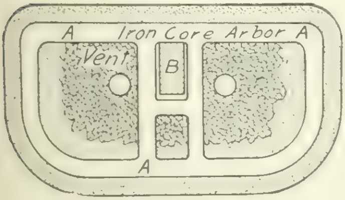


Fig. 67. Arbor.

Often, when but one or two large cores are wanted, the cost of making a box is saved by sweeping up the core. This is illustrated in the pipe core shown in Fig. 68.

The pattern maker gets out two core boards and one sweep. The boards are made by simply nailing together three thicknesses of $\frac{7}{8}$ inch stuff, with the grain of the middle piece crossing that of the others to prevent warping. The outer edges of the boards have the exact curve of the outside of the pipe pattern, and at the ends is tacked a half section of the core, shown at *a a*. One sweep does for both boards. The curve is cut the exact half section of the core The edge *b* equals the thickness of metal in the casting, and the stop *c* acts as a guide along the outer edge of the board.

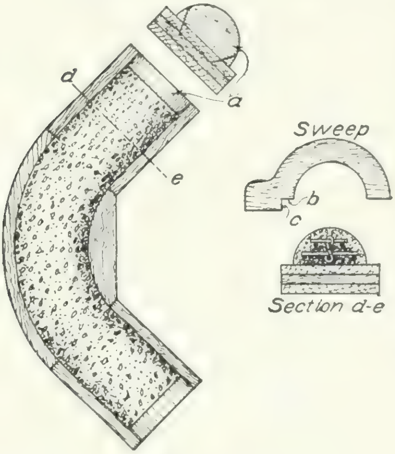


Fig. 68. Pipe Core,

In making up this core a thin layer of core sand is spread on the board and the outline of the core swept. On this the rods with their lifting hooks are bedded, and the vent cinders carefully laid along the

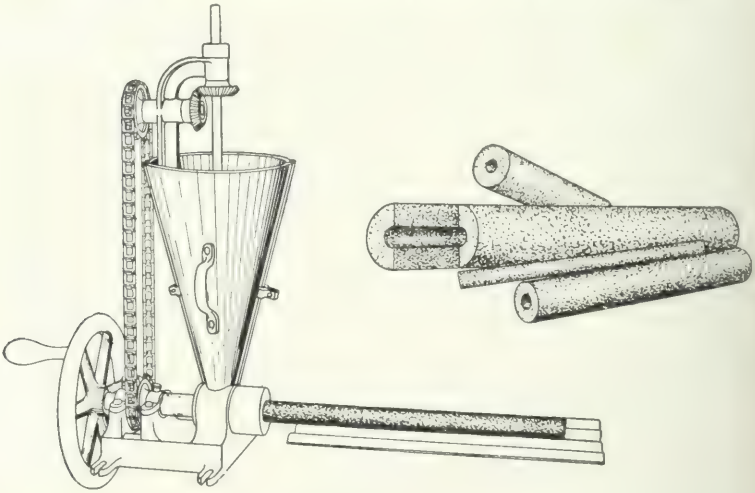


Fig. 69. Core Machine.

middle. The whole general shape is then rammed up in core sand larger than required, and by using the sweep it is brought to exact size. The core is then slicked off, blackened and baked while still on the board. When both halves are dried, they are pasted together, the same as with smaller work. To prevent breaking the lower half when turning it over to paste, it is rolled over on a pile of heap sand.

For making "stock" cores, round or square, several styles of core machines have been put on the market within the last few years, of which the accompanying cut, Fig. 69, is a good representative. This is arranged to be driven by hand or by power. The core sand is placed in the hopper and by means of a horizontal worm at the bottom, it is forced through a nozzle under just the right pressure to pack the core firmly. A clean cut vent hole is left in the middle of each core. As the core is forced from the nozzle it is received on a corrugated sheet steel plate, which is moved along to the next groove when the core has run to the full length of the plate.

The advantage of the machine is that with it an apprentice boy can produce a true, smooth, perfectly vented core, in very much less time than could possibly be done by hand ramming.

SETTING CORES

The following examples show typical ways of setting and securing cores in molds and of connecting vents.

A bolt hole core, shown at A, Fig. 70, illustrates the simplest form of core to set. Only a drag print is necessary; the flat top of the core should just touch the cope surface of the mold. The level may be tested by a straight stick or by sighting across the joint. If the core is too long, one end may be filed off a little; if too short, a little sand may be filled into the bottom of the print. For longer cores, especially

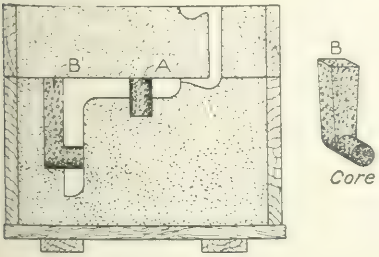


Fig. 70. Bolt-Hole Core.

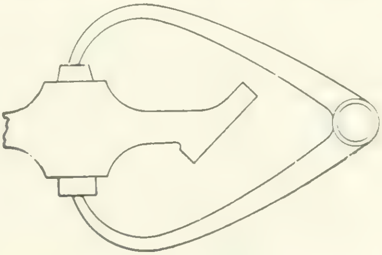


Fig. 71. Calipers.

hub cores, a taper print is placed on the cope side of the pattern, and the same taper is given to the end of the core; this guides it to the exact center when the mold is closed. Numerous examples are shown in Pattern Making, pages 103 to 107. The exact length of the core should be obtained from the pattern with a pair of calipers, as shown in Fig. 71. One point of the calipers should then be placed on the taper end of the core, and the print filled in or the core shortened in case of variation from the right length.

It is well to make a vent hole from the center of each print before setting the core.

With pattern and core boxes properly made, little difficulty should be experienced in setting small horizontal cores for hollow bushings, pipe connections, etc. (See Pattern Making, Figs. 111, 186 and 191.) The core must fit the print or a poor casting will result. The sand supporting the prints must be tucked firmly enough to withstand the lifting pressure on the core. A scratch with the point of the trowel along the joint surface from the end of the print to the edge of the flask, will usually take care of the vent.

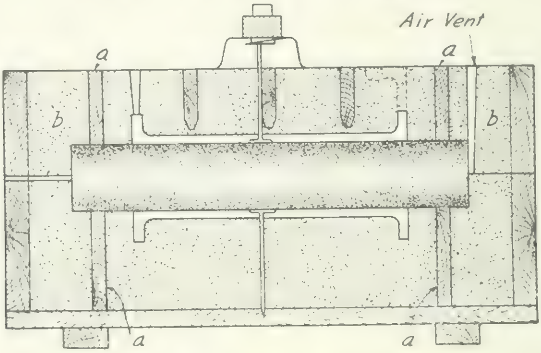


Fig. 72. Body Core, Supported.

For larger cores of this character, crossbars are nailed in both drag and cope made to fit snug against the core print. See *a a a a*, Fig. 72. These hold the core absolutely firm. The spaces *b b* in the cope, are not packed until the core is set, when it is a simple matter to ram these spaces and take off an air vent directly from the center of the core.

In setting chaplets, the height of the lower one may be tested with a rule, with a straight edge rested on the prints, or by a guage similar to that shown in Fig. 73. A small boss is usually formed by pressing the trowel handle into the mold where the chaplet is to go.

The cope chaplet is not fastened until the mold is closed, then the stem can be properly wedged down under a bar clamped across the top of the mold.

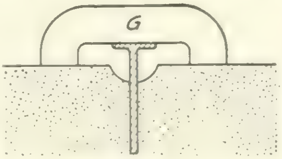


Fig. 73.

There are two methods of coring holes below the level of the joint. One is shown clearly in Fig. 74. A "stock" core is set in the bottom of the prints; a wooden template, shown at *b* and *b′*, is set over the core, and the print *a* is then packed with molding sand or "stopped off," as it is termed.

The other method is shown at B and B′, Fig. 70. Here that part of the core which will shape the hole through the casting, is formed on the end of a core which exactly fills the print. A single operation sets the core and stops off the print For this reason this method is used where a large number of such holes are to be cored.

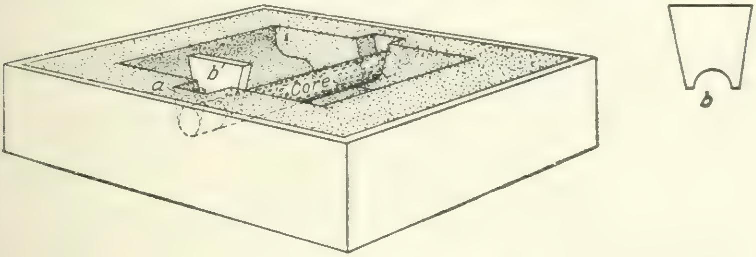


Fig. 74. Setting Core Below Surface.

In work where a hole must project well into the casting but not all the way through it, a balanced core is often used. Such a case is illustrated by the rammer head, Fig. 75. When making this core, let the vent extend through the entire length, then stop up the vent at the small end with a bit of clay after the core is baked.

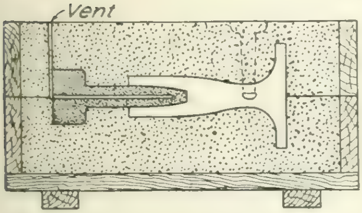


Fig. 75. Small Balanced Core.

It is not always practicable to enlarge the print as shown here, but when possible, it reduces the length of print necessary to balance the projecting end and ensures accurate depth to the hole.

Heavy projecting cores must be supported by chaplets, as illustrated in Fig. 76. Vents may be taken off through a channel and air riser as explained in the section on venting. Fig. 77 shows the shape of the print on the pattern for this mold at *a*, the pockets formed by the core are shown at *b b*; and *c* indicates the position of the gate.

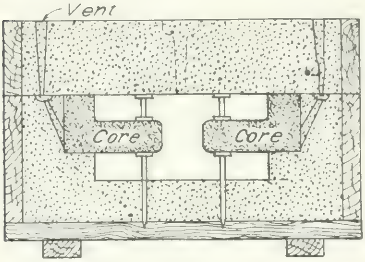


Fig. 76. Large Balanced Core.

A core is frequently used to avoid a deep lift for the cope. Suitable wire hangers, shown at *a*, Fig. 78, are bedded in the core when it is made. In setting the core small annealed wire about No. 20 or No. 24 gauge, is looped through the hangers, passed through small holes made in the cope, and fastened with a granny twist over an iron bar on top. This bar should bear on the sides of the cope and the core be brought up snug in its print by wedging under its ends. The "rigging" need only be strong enough to support the weight of the core, for the pressure of metal will force this core firmly into its print with little danger of shifting it. For heavy cores a lifting eye, as previously illustrated in Fig. 66, takes the place of the wire hanger, and the core is hung by means of a hooked rod with a nut on the end. As shown in Fig. 79, this rod passes through a long washer which bears on a pair of rails, or similar stiff rigging.

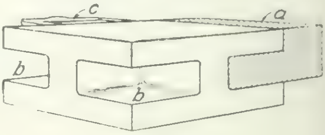


Fig. 77.

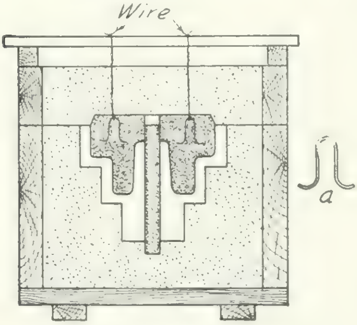


Fig. 78.

Where possible, the placing of cores in the bottom of molds should be avoided, for in this position, being much lighter than molten iron, they must be secured against a pressure tending to float or lift them

This pressure is proportionate to their depth below the pouring basin. But the metal at the bottom of a mold is cleaner and more sound than that at the top. Therefore, planer beds, large face plates and pieces of this character, are usually cast face downward, making it necessary to anchor the T-slot cores in the bottom of the mold.

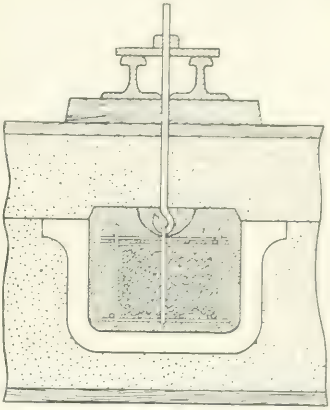


Fig. 79.

In some cases such cores may be held down by driving nails so that their heads project somewhat over the ends of the core, as shown in Fig. 80. If this method is not strong enough, pointed anchors, with a foot on one end, are run through a hole in the core, and are carefully driven into the bottom board. See Fig. 81. Where the work is bedded into the floor a plank must be set to receive these anchors just below the cinder bed. As in the case of lifting eyes, the holes in the core, into which the foot on the anchor is driven, are smeared with oil and stopped off with green sand.

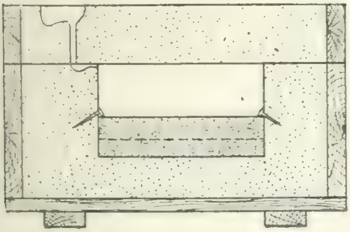


Fig. 80.

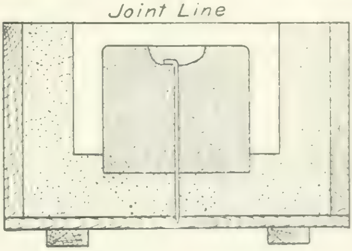


Fig. 81.

DUPLICATING CASTINGS

Devising methods for increasing production and decreasing its cost is one of the important problems of modern engineering in the foundry as well as elsewhere. In the jobbing foundry where there is a great variety, not only in the patterns themselves, but in the number of castings called for from each pattern, the molder makes up a sand match as already described.

On this match he arranges such an assortment of patterns as will fill his flask and beds them into place. From a well-made sand match two or three hundred molds may be made up. When the desired number of castings is made from one pattern on the match, that one is removed and another one which will fit in its place is substituted.

For manufacturing purposes thousands of the same casting may be required calling for more durable patterns and match. Metal patterns are made and as many as can be cast in a flask are soldered to a smoothly finished metal gate pattern. With a draw screw inserted in this gate, all of the patterns may be drawn at once. Two steady-pins should be screwed and sweated into the drag side of the gate pattern. These should be of small round brass rod and project below the deepest point of the patterns. They guide the pattern as it is being drawn and prevent it from swaying and breaking the edges just as it leaves the sand. Patterns so arranged are termed "gated patterns."

When such patterns have a flat joint, a special mold board should be provided and the patterns stored on the same board. When the joint is irregular, a permanent oil match should be made. Make a strong hardwood frame the size of the flask and about 1 inch deep, with the bottom board arranged to screw on to the back. Nails should be driven into the inner sides hanging parallel to the bottom board. Measure the quantity of sand needed to fill this match. Mix thoroughly and put through a fine sieve, while dry, one-half this quantity of burnt sand, one-half new molding sand, and about one-fortieth litharge. Temper the same as molding sand, using boiled linseed oil. Ram up drag and joint the mold very carefully. Put on the match frame and ram up with the above mixture; strike off, and screw on bottom board. Remove drag and allow the match to dry for a day with the patterns left in it. A coat of shellac when dry will improve the surface. Fig. 82 shows a set of gated patterns bedded in a hard match.

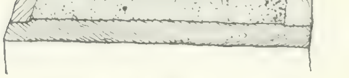


Fig. 82. Oil Match.

MOLDING MACHINES

Although there are many styles of molding machines on the market, there are practically but three separate types: Those designed to simply draw the pattern; those which only ram the flask, and those where the mechanism is arranged to perform both of these operations.

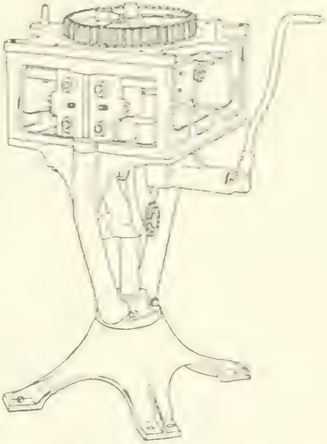


Fig. 83. Molding Machine.

Machines are used to make it possible to turn out larger quantities of small work or to simplify the production of difficult castings. The kind of machine used will vary according to the line of casting to be made. Iron flasks are used with these machines for medium weight casting, while for light work the snap flask is almost universally employed.

In Fig. 83 is shown a molding machine of the first type spoken of above. The pedestal base of the machine has a flat top. The stripping plate is supported above this by a rigid open framework. Working in guides carried on the sides of this framework is the drawing frame made to raise or lower by a strong crank and connecting rod. On top of this drawing frame and parallel to the stripping plate is

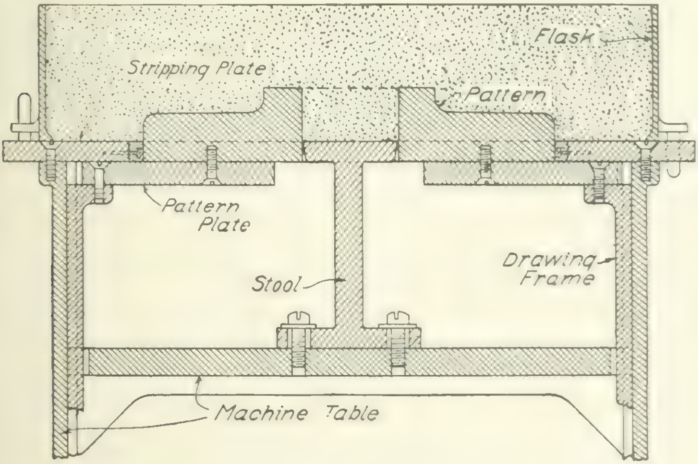


Fig. 84.

screwed the plate to which the pattern is fastened. The stripping plate is cast with an opening which leaves about 1 inch clear all around the pattern. When both pattern and stripping plate are properly set in place, this space is filled with babbitt metal; this being an easy way to secure a nice fit.

In many cases there will be an inerior body of sand to be supported when the pattern is drawn. To accomplish this *stools* are used. A leg screwed into the stool plate supports the stool at the exact level of the stripping plate. The *stool plate* is fastened to the flat top of the machine inside of the box-like framework which supports the stripping plate. See Fig. 84.

The gear wheel mounted in Fig. 83, would be a difficult pattern to duplicate by simple hand drawing; the machine insures a perfectly clean draw. A box is inverted on the machine, rammed, vented and struck off. A movement of the crank lever at the side draws the pattern. The mold is removed and set on a level sand floor, thus doing away with bottom boards. A second stripping plate and pattern is used for ramming the cope boxes.

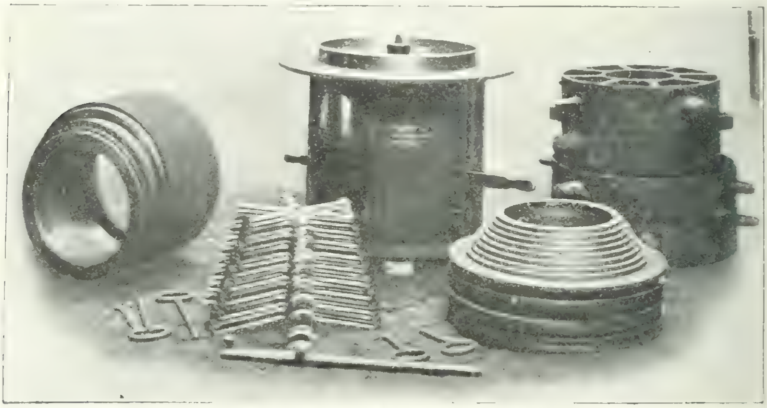


Fig. 85. Pulley Molding Machine.

Pulleys are manufactured on molding machines of this type, as shown by the equipment illustrated in Fig 85. The rim patterns have the form of long hollow cylinders and can readily be set for any desired width of face. The hub carrying the core print separates from the spokes, lifts off in the mold and is drawn by hand. The arm patterns are so flat and smoothly rounded that the mold is easily lifted off of them with little fear of breaking the sand. Cope and drag molds are both alike for a pulley mold.

Fig. 86 shows a type of machine which only packs the sand. Here the *patterns* are carried on *two sides of a plate* set between the cope and drag. Both boxes are filled with sifted sand and set on the machine. The boards are made to slide inside of the flask. The molder's weight on the lever compresses the sand.

The sprue is cut by a thin hollow steel tube called a *sprue-cutter*, which is pressed through the cope sand by the molder before separating the flask. In separating the mold the cope is first lifted from the drag and the plate is gently rapped and lifted from the drag. To make a clean lift when parts of the patterns project in the cope, a second molder raps with an iron bar between the battens of the bottom board while the cope is being drawn off.

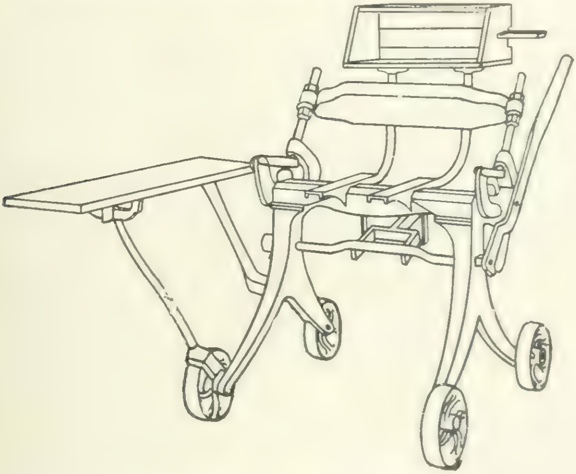


Fig. 86. Molding Machine, or Squeezer.

Such machines are used chiefly on thin work which will vent and solidify very rapidly—for the outer surfaces of the drag and cope are apt to be rammed so hard that they might choke the vent on heavier castings.

Fig. 87 shows the operation of the lever mechanism by which one movement draws the presser head over into place and then pulls it down to compress the sand.

With the third class of machine both hand and power are employed for the operating. A hand machine, built on the same lines as the previous example, is shown in Fig. 88. With this machine *gated patterns* are mounted on a *wooden board or hard match.* Snap flasks are used and when the size of the work will permit, both cope and drag parts are set up side by side on the same machine.

The amount of sand to be compressed is regulated by the depth of the *sand frame* which is set on top of the boxes. To avoid ramming the higher portions of the pattern too hard a thick block is fastened to the *presser head.* This block is hollowed out to conform with the shape of the patterns, as shown in the small cut. This excess is struck off before the patterns are drawn. A movement of the lift lever raises the lift table. This in turn raises four pins which pass through the corners of the pattern board, engage the edges of the flask and lift it perfectly straight off of the patterns. The end of a rapping bar may be seen under the pattern board of the cope box. With this the board is rapped while the lift is being made.

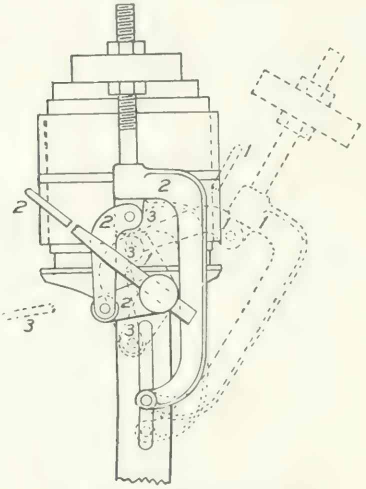


Fig. 87. Lever Mechanism.

Compressed air, steam, and in some styles, power transmitted by belting, are used for operating many molding machines. Compressed air is, however, more frequently met with. Fig. 89 shows a modern machine. The sizes range from 14 x 20 inches to 40 x 90 inches.

In operation the facing sand is tucked by hand, and the flask and sand frame filled. The presser head is swung forward but remains stationary, and the whole machine table, bearing patterns and flask are forced upward against it, by means of a cylinder underneath the center of the machine. Two or three blows are given as if by a steam hammer.

Either a stripping plate, pattern board, or pattern plate is used. As a substitute for rapping the patterns a small pair of cylinders is attached to the frame which carries them. These cylinders contain a small piston which is driven back and forth very rapidly, giving a trembling motion to the patterns. This attachment is called a pneumatic vibrator.

A rubber tube with a nozzle is conveniently attached to the compressed air pipe and provides a ready means for the molder to blow his mold clean. The force of this air is regulated by a spring valve attached to the nozzle.

On the large machines all operations, even to the swinging of the presser head, are accomplished by compressed air, controlled by a few conveniently placed levers.

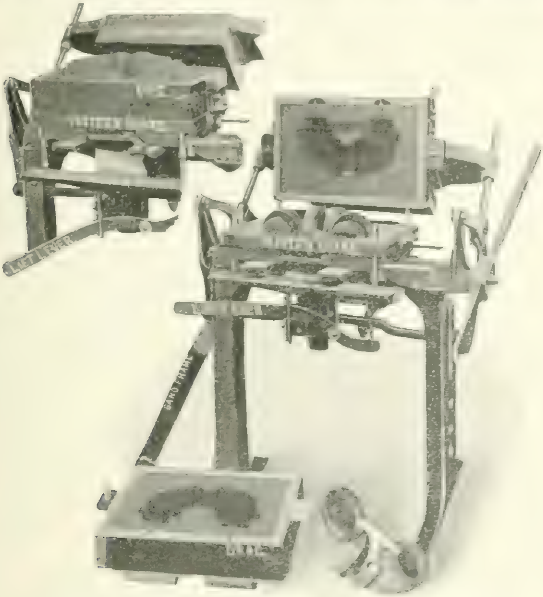


Fig. 88. Squeezer, with Device for Drawing Patterns.

The advantage of molding machines lies in the fact that they can be operated with practically unskilled labor, because there is no skill required in drawing the pattern, in repairing the mold, or in gating, and in many, none required in packing the flask. All of these are points which ordinarily call for sound judgment and a high degree of skill on the part of the molder. The limitation of the simple squeezer due to hard surface ramming, has been mentioned.

The tendency of molding machine practice in the jobbing shops is toward a hand-rammed, stripping-plate machine, because the jobs may be changed quickly and the more intricate patterns can be rammed just right. The great expense of metal patterns and stripping plate is being overcome by the use of ordinary wooden patterns and a stripping plate made of well-seasoned oak, which has been boiled in paraffin to prevent it from warping.

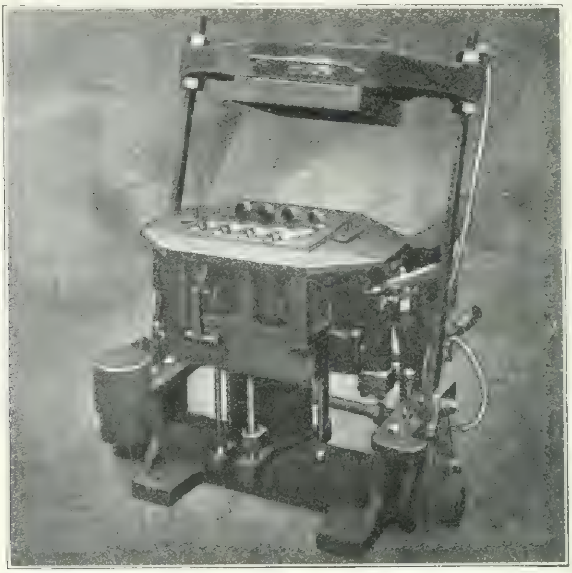


Fig. 89. Molding Machine. (Rams by Power and Draws Patterns Automatically.)

DRY SAND WORK

This branch of molding becomes a separate trade in shops where the work is done continually. The dry sand molder must use the same precautions as the green sand molder in setting gates, risers, and fastening his sand with crossbars and gagers. At the same time he works with a core sand mixture next his patterns and backs this with a coarse molding sand. So that he must combine the skill and judgment of both green sand molder and core maker. The venting of dry sand work must be ample as in the case of cores, but it is simpler than in core work, because the core mixture surrounds the casting so that vents may be taken off in all directions.

Iron flasks are used, generally provided with trunnions to facilitate turning. The facing mixture is the same as that used for making large cores. See Core Making. The remainder of the flask is packed with the same sand after it has been used. The patterns are made and used the same as with green sand, only they should be brushed over with linseed, crude-oil or other heavy oil before ramming. In some shops oil is brushed over the joint before parting sand is thrown on. After the pattern is drawn, the mold is finished by applying a heavy coat of good black wash. When the sand has absorbed the moisture so that all glisten has disappeared, this blacking is slicked over. Great care must be exercised in this operation, for too much slicking will draw the moisture to the surface again and result in scabs on the casting.

Engine cylinders are a representative line of work for dry sand. Consider the simple type of cylinder shown in Pattern Making, page 115, to have a bore of from 16 to 26 inches with the exhaust-outlet flange placed above the center of the cylinder. To facilitate setting the cores the pattern will be split through the steam chest. The flange just mentioned will be molded in the drag; it should be made loose and draw in the opposite direction from the main pattern. The cylinder core will be made on a "barrel" (explained later on page 67) and the mold poured on end to insure sound metal and to reduce the casting strain on the port cores. The flask is made with a round opening in one end to allow the core to project through it. This opening is larger than the diameter of the core to allow for gates and risers. There must be another opening at the side of the flask opposite the

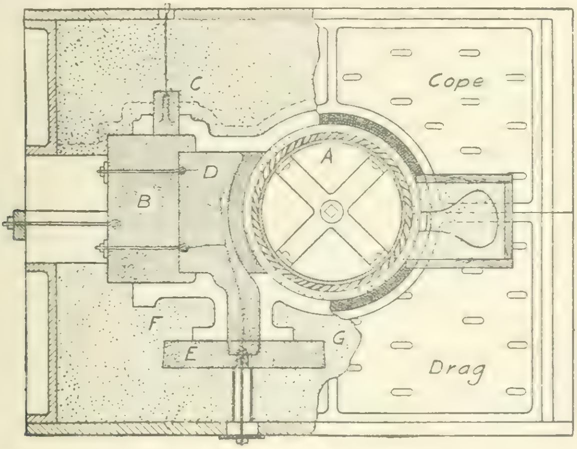


Fig. 90. Molding a Cylinder.

steam chest core to provide for fastening these cores. Iron plates serve for flask boards and there should be a hole in the drag plate opposite the exhaust core to allow for venting and fastening its end.

One half of Fig. 90 shows the end view of the flask. The other half shows a section through the middle of the completed mold. Here A is the hollow cylinder core, B is the chest core, C the live steam core hung in the cope, D the exhaust core. The flask is packed in a manner similar to green sand. The method of molding the exhaust flange, however, has not previously been explained. To do this, proceed packing the drag until the pattern is covered. Tuck the facing carefully underneath the flange, setting in rods as in core work, to strengthen the overhanging portions. Make a flat joint, F G, at the level of the top of the flange, then carefully fit over the print of the flange the cover core, E, and fix its position with nails driven into the joint at its corners. Now remove the cover core, draw the flange and finish that part of the mold with black wash and slicking. When this is accom-

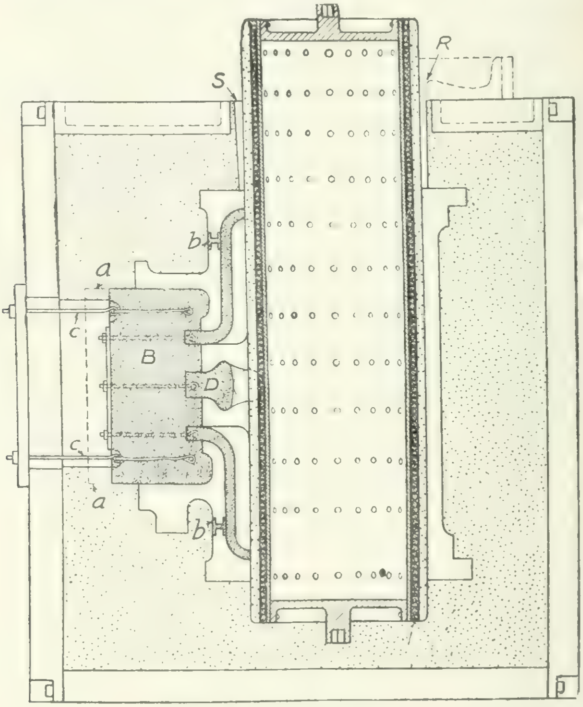


Fig. 91. Plan on Drag.

plished, replace the cover core, place a short piece of pipe over its central vent, and finish ramming the drag. This method may be used in many cases, both in dry sand and green sand work where a small detail of the casting requires a separate joint surface.

A sectional plan looking down on the drag is shown in Fig. 91. When the mold has been properly finished and baked, the drag is brought from the oven and set on a pair of stout horses. The cylinder core is first set in place, then the exhaust core is set in its drag print and held close to the cylinder core, while the port and chest cores, previously pasted and fastened, are lowered into the chest print. The chest print is cut a little long at *a a*, to allow its core to be drawn back slightly while the exhaust core is entered into its place between the port cores. Then all of the cores are set forward into position, the chaplets *b b* set, the space *a a* tightly packed again, and the anchor bolts *c c* placed in position and made fast. The drag print of the exhaust core is made fast from underneath the drag plate. When all the cores have been firmly fastened, the cope is closed on, the two boxes clamped at the flanges, and set up on end. The runner R and the riser S were cut and finished before baking; the basins must be built in green sand after the mold is closed.

MAKING A BARREL CORE

Loam is used here for the outer shell of the core. It is probably the simplest job in which a loam mixture is employed, and is made by a core maker more frequently than by the higher paid loam molder. Barrel cores are used where the core is long and can best be supported at the ends only; for example, in gas and water pipes and cylinder work.

Loam is a facing mixture, of the consistency of mortar, applied to the face of the core or mold. It contains fire sand with a bond of strong porous molding sand moistened with a thick clay wash. A small proportion of organic matter in the shape of horse manure is put in to aid the bond and to leave the crust of loam more fragile by burning out as the casting cools. Proportions of the mixture will vary according to locality, but the principles already cited hold here as with other molding compounds. With too much bond the loam works easier but tends to choke the vents when casting. With not enough it will be weak and liable to break, cut or crumble under strain. A typical mixture is as follows:

	Mixed by Hand	Mixed by Mill
Fire sand	10 parts	10 parts
Strong coarse molding sand	4 "	3 "
Horse manure	1½ "	2 "

Wet with thick clay wash.

The advantages of loam cores are that they are lighter, cheaper to make, and carry off the gases faster than do dry sand cores.

The method of making barrel cores is as follows: A piece of pipe about three inches smaller than the outside diameter of the core is selected to form the center. The pipe is perforated with a large number of holes. If the pipe is more than three or four inches in diameter, centers or trunnions are riveted in the ends to serve as bearings. The pipe is arranged to revolve freely on a pair of iron horses, as shown in Fig. 92. A crank handle is attached by which the pipe may be turned. A couple of wraps of hay rope are first given around one end of the pipe and the loose end pinned flat by a nail run under these strands. Tight wrapping is then continued to the other end of the pipe where the rope is fastened in a similar manner and cut off. Hay rope should be made of long wisps tightly twisted. Sizes vary from ¾ to 1 inch. Where only a small amount of hay rope is used, it is bought ready made. Foundries using large quantities are equipped with one or more machines built especially for making this rope.

The first coat of loam is rubbed on with the hands, then well pressed in with the flat side of a board as the barrel is slowly revolved. When this has set, the core board, A, is placed in position, and the roughing coat worked on to the core to within about ¼ inch of finished size. The core is now dried in the oven. Placing the core again on the standards, the finishing coat of "slip" is applied with the core board while the core is still hot. The diameter is tested with calipers and brought to required size by slight adjustment of sweep board A. When the core has been built to size, move the loam back from the edge of board A, then withdraw the board while the "barrel" is still in motion.

Slip or *skinning loam* is made by thinning regular loam as it is rubbed through a No. 8 sieve. The heat of the core is usually sufficient to dry this slip coat enough so that black wash may be brushed on and slicked, as in dry sand work, before running the core into the oven again for its final baking.

The service of the hay rope on a barrel core is twofold. It furnishes a surface over the smooth metal of the barrel to which loam

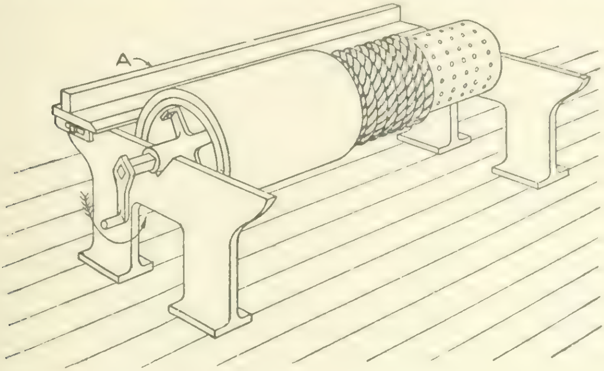
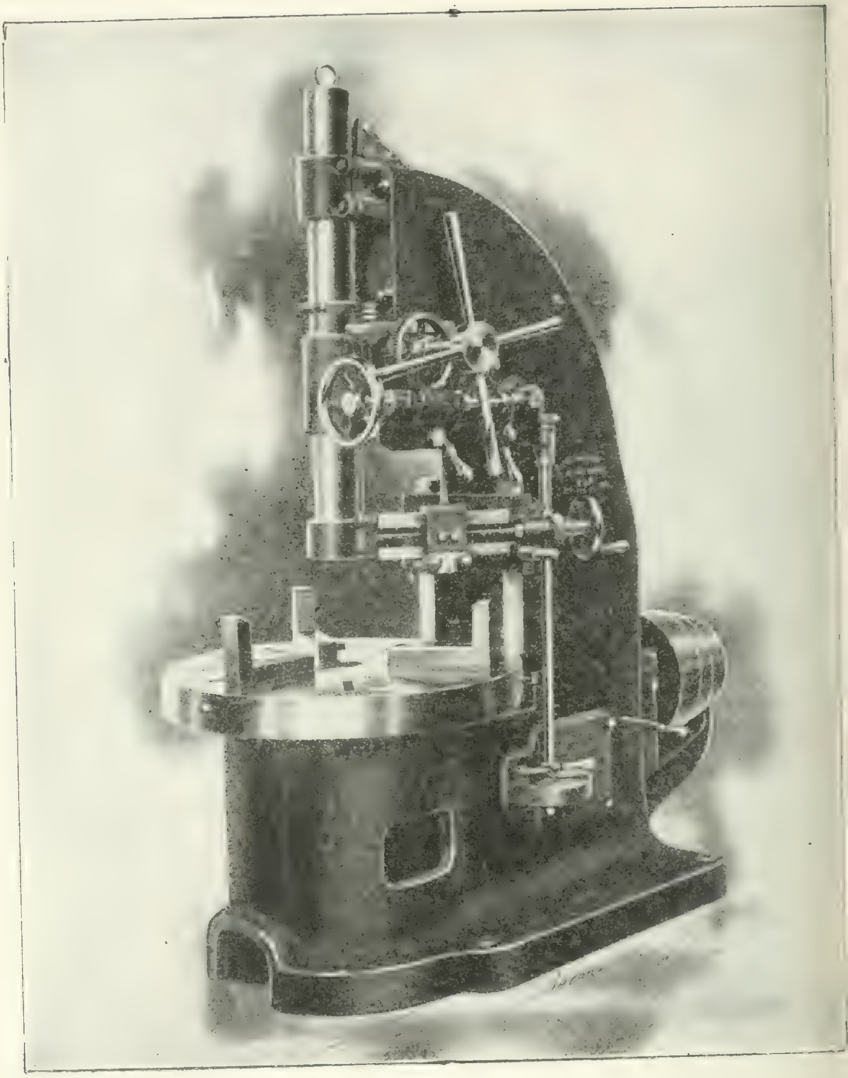


Fig. 92. Making Loam Core for Cylinder.

will adhere; and it is elastic enough to give as the casting shrinks around the core. The hay slowly burns out after the casting has set, and this frees the barrel so that it can easily be withdrawn and used again.



CAR-WHEEL BORER.

Baker Brothers

FOUNDRY WORK

PART II

LOAM MOLDING

The loam molder requires the greatest all-around skill in the whole range of foundry work. He must know all the tricks of core room and dry sand shop, and most of those in green sand. Added to all this he must have a practical working knowledge of the principles of drawing and must possess to a large degree the foresight of the designer.

In order to save time and lumber in the pattern shop, only a set of sweeps are provided if the mold is simple, and these with blue prints of the piece wanted, is all the molder has to work from. In intricate work, such as a modern Corliss cylinder, a skeleton pattern carrying the steam chests, etc., in accurate position is made. And in some very crooked work a pattern is furnished complete. As a rule, however, the loam molder must rely upon his own skill and ingenuity for the best method of constructing each detail of the work.

Rigging. The equipment for the loam floor varies in different shops. In Fig. 93 is shown the essential features of an equipment for sweeping up circular forms.

The **spindle** *a* should be large enough not to spring when being used, and long enough to conveniently clear the highest mold. A piece of 2-inch shafting is a handy size, for with it the sweeps may be made uniformly 1 inch less than the required diameter and placed snug to the spindle when set up and correct size of mold is ensured. This spindle should revolve smoothly in a *step b*. The step shown may be set at any convenient place on the floor It has a long taper bearing, (see section A), capable of holding a five-foot spindle without need of any top bearing for same. The three arms serve to make the step set firm, and upon them any plate may be readily leveled up. Where a tall spindle is used the spindle socket will be more shallow, the step may be cast without arms and be bedded in the floor. The top of the spindle is steadied by the *bracket c*. This must carry a bearing *box* so designed that the spindle may be readily set in position or removed. And the bracket must swing back out of the way when any parts of the mold are to be handled by the crane.

The sweeps are attached by means of the *sweep arm d.* The detail B shows one method of clamping sweep arm to spindle by using a key. The arm is offset so that one face hangs in line with the center of the spindle. Bolting the face side of the sweep to this brings the working edge in a true radial plane. *Sweeps* are usually made from pine about 1¼ inches thick. The working edge is cut to the exact contour of the form to be swept, and then beveled so that the edge actually sweeping the surface is only about ¾ inch. For very accurate work or when sweeps are to be much used, the edge is faced with thin strap iron to prevent wear.

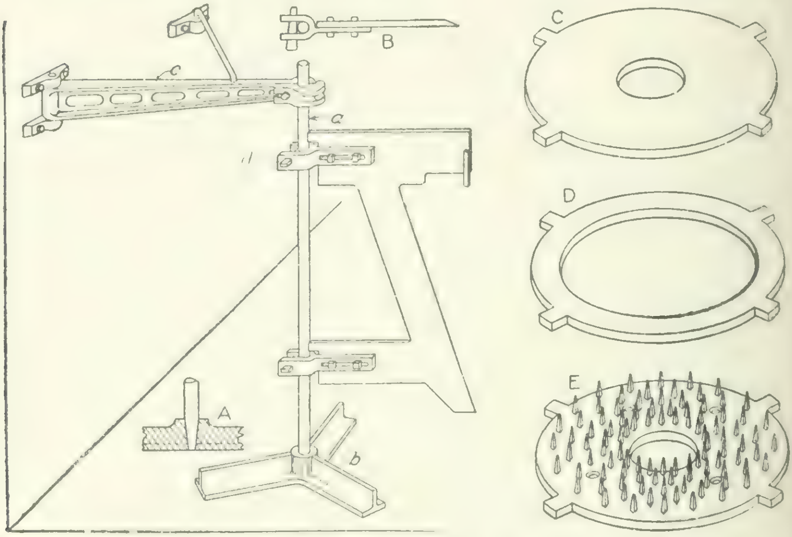


Fig 93. Rig for Loam Work.

We have seen that the walls of green and dry sand molds are supported by sand packed into flasks and that these flasks may be lifted, turned up sideways or rolled completely over to suit the convenience of the workman. The facing which forms the wall of a loam mold is supported by brickwork built upon flat *plates* of cast iron, and laid in a weak mortar of "mud." From the nature of their construction, therefore, these molds must always be kept perpendicular when being handled. The parts may be raised, lowered, or moved in any direction horizontally, but they must not be tipped or rolled over.

The plates are cast in open sand molds, as illustrated in Fig. 56. Two methods are employed to provide for handling them by the crane, either *lugs* are cast on the edges of the plates (see Fig. 93, C, D, and E), or wrought *staples* are cast in the plates, as shown in the example B, Fig. 94, or in the crown plate of the main cylinder core, Fig. 97.

Three typical plates for a loam job are shown in Fig. 93. C is the *building plate*, it should be at least 18 or 20 inches larger than the largest diameter of the casting to be made, and thick enough to support the weight of the entire mold without springing. D shows a "*cope ring;*" its inside diameter should clear the casting 2 inches on all sides. The face should be 8 to 12 inches wide, depending upon the height of the mold. E shows a *cover plate;* its diameter will equal the outside diameter of brickwork on that part of the mold which it will cover. Here the loam facing is placed directly on the iron, and must be supported when the plate stands vertically or is turned completely over (C, Fig. 96). To hold the loam in this way, "*fingers*" or "*stickers*"

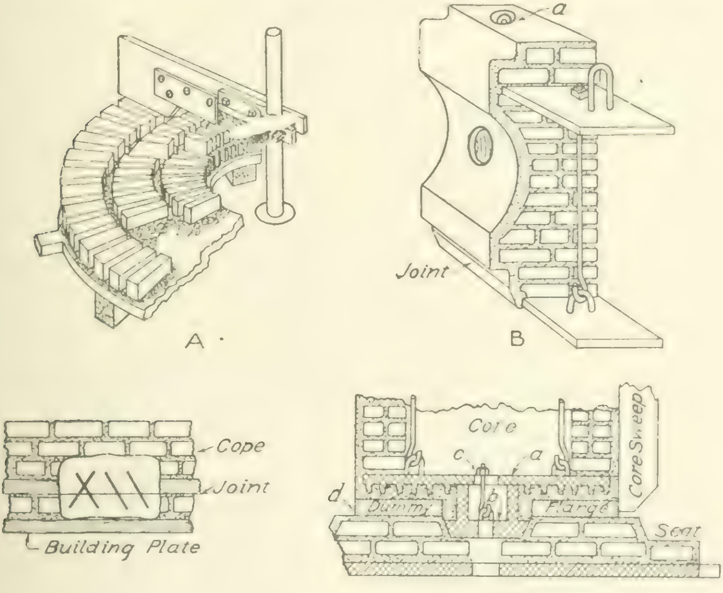


Fig. 94. Laying up Loam Work.

are cast on these plates. This is accomplished by simply printing the end of a tapered stick into the bed of the open mold which shapes the plates. These "sticker plates" are often used for a purpose similar to core E, Fig. 90, and shape the outer face of a picked-out flange. This is illustrated in D, Fig. 96.

Materials. Common *red bricks* are best for making loam molds. They should be free from glaze and have a uniform texture, so that

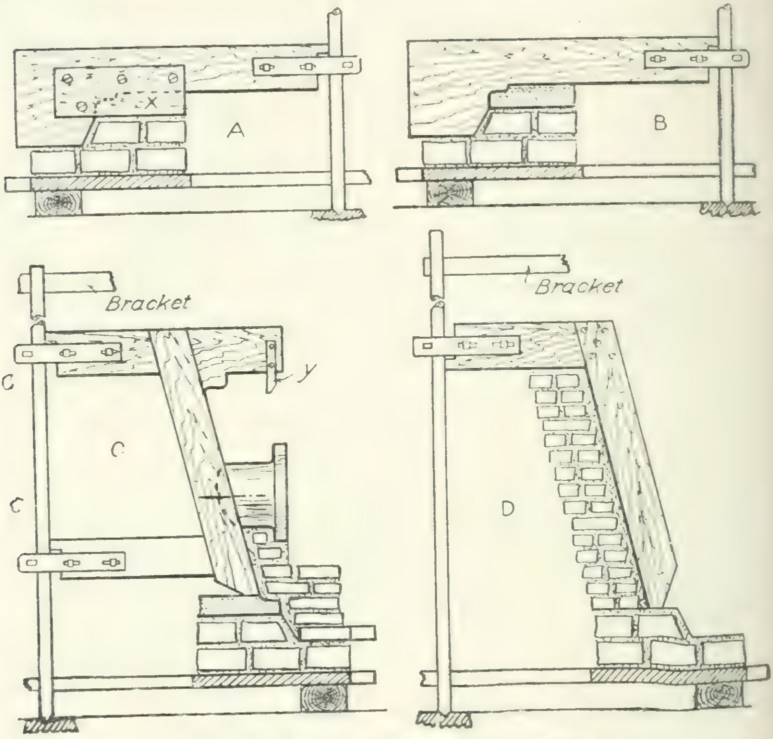


Fig. 95. Steps in Sweeping up Type Mold.

they will break clean when it is necessary to fit them to the shape An old 12-inch half-round file makes a handy tool for cutting these bricks. Sometimes bricks are molded up from loam, and air-dried. These are much more fragile than red bricks, and may be used in pockets, or where the shell of the casting is quite thin, and ordinary brick might resist the shrinkage strain to such an extent as to endanger cracking the casting.

For laying up the brickwork, "*mud*" is used, loam facing being applied only to those surfaces which come in actual contact with the iron. Mud is made from burnt loam or old floor sand, mixed with clay wash to the consistency of mortar.

The composition of loam facing and "slip" have already been given under head of Making a Barrel Core.

Cinders are an important material in this work. Their size will depend upon their position in the mold. For working in between the bricks they should be crushed if necessary, put through a No. 4 sieve to remove smallest pieces, then passed through a No. 2 sieve to remove the larger pieces.

Principles of the Work. The names of the main parts of a loam mold differ somewhat from those applied when molding in flasks. As will be seen from the section, Fig. 96, there are three main divisions in the mold: A, which corresponds to the drag in a three-part mold is called the "*core*." B, which corresponds to the cheek is called the "*cope*" in loam work. And C, which serves the same purpose as the cope of a green sand mold, is spoken of as the "*cover*" in loam molding. When the central core is actually made a separate piece as in Fig. 97, the lower part of the mold is called the "*bed*" or "*foundation*."

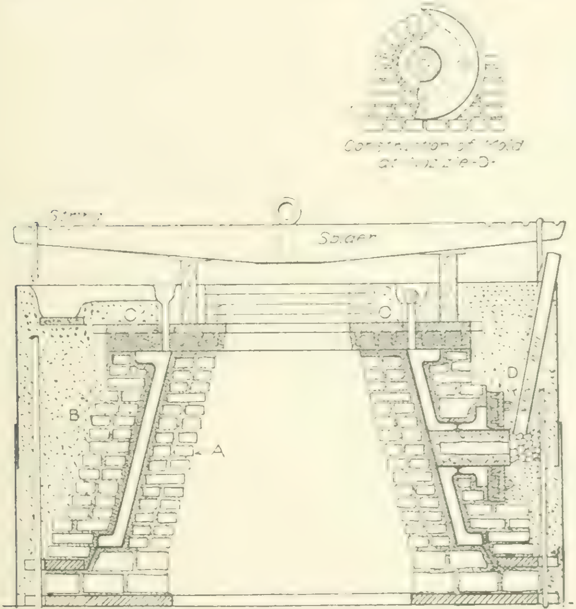


Fig. 96. Complete Typical Loam Mold.

In *laying up* a loam mold, set the plate central with the spindle and approximately level. Then set the sweep and finish leveling the plate until repeated measurements at the four quarters of the circle show a uniform space between the lower edge of the sweep and the surface of the plate. For the building plate this measurement should be 5 inches; for a sticker plate the sweep should clear the sticker points by $\frac{1}{2}$ to 1 inch according to the thickness of the casting.

The *hands* are used in *spreading* mud or loam upon the plates or brickwork when building the mold. The bricks must always be set well apart, leaving a space at least the width of a finger between them. *Fill* in these *spaces* with fine *cinders*. The reason for this is fourfold. It facilitates *drying;* it provides good *vent;* it will *give* or *crush* sufficiently when the casting shrinks not to cause undue strain; and it *reduces* the *labor* in cleaning. In each course of bricks the joints should lead as directly as possible away from the casting, but the joints should be broken between courses. These points are illustrated in the sketch A, Fig. 94. As shown, the first two courses of the core are usually set edgewise. For the rest of the core and for the cope, the bricks are laid flat. These bricks run lengthwise around the circumference, with a course of "headers" about every four to six courses.

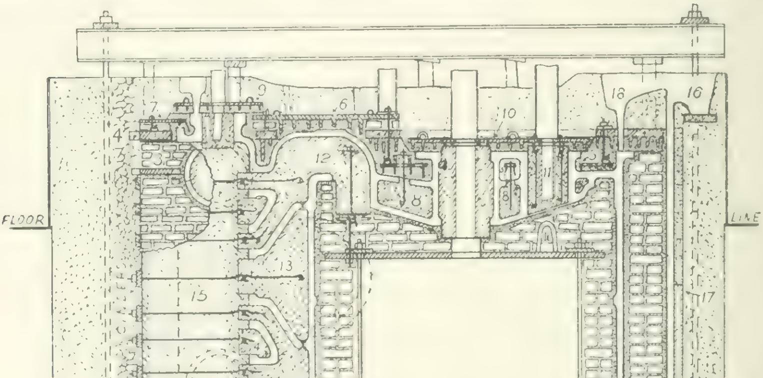


Fig. 97. Loam Mold for Marine Cylinder.

Cinders between the bricks form the ordinary means of leading the vent from the loam facing. In confined places or "pockets," as for example, between the flange D and the main casting, Fig. 96, additional provision is made by laying long wisps of straw between the courses of bricks. The service of the straw is similar to the hay rope of a barrel core.

The *joint* in loam work is made by a plate lifting away from a loam seat or two loam surfaces separating one from another. In forming the first of these the loam seat is swept up and allowed to partially set, then the surface is brushed with oil, and parting sand thrown over it. The seat should then be soft enough to allow the iron plate to sink into it sufficiently to find a good bearing, while the oil and parting sand will prevent the loam facing from adhering to the underside of the plate. For the loam to loam joint, the same method is used, but the loam is allowed to set somewhat harder before building the joint against it. The angle of the main joint should be about 1 in 4 inches.

To insure the different parts being put together for casting in exactly the same position in which they were built, a guide surface of loam is smoothed across the joint at three or four convenient points on the outside walls of the mold. These surfaces are each marked differently with the edge of the trowel, similar to the cut at C, Fig. 94.

To properly separate and finish some molds it is necessary to lift away a portion of the mold before lifting the main part. Such a portion is called a draw-back. The draw-back is always built up in position against a pattern or sweep. With the cover plate, which on a smaller scale often serves the same purpose, (see D, Fig. 96), a flat joint is made on the outer wall of the mold, but the cover plate is swept up separately. At No. 3, Fig. 97, is shown a draw-back which carries but a few courses of brick. It may be lifted away by lugs cast in the draw-back plate with little danger of displacing its brickwork in handling.

If the shape of the draw-back renders it impracticable to handle it by the lower plate alone, the brickwork should be bound together by means of hook bolts which clamp on a top plate set sufficiently below the upper joint to be entirely protected from the metal. This upper plate has staples cast in it by which the whole draw-back may be lifted. At B, Fig. 94, the typical construction of such a piece is illustrated. The drawing shows one half the length of the brickwork removed to bring out more clearly the rigging used. The upper end of the second lifting staple shows at *a*, with the loam cut neatly away to allow hooking into the staple.

Where the main core will lift away or will be covered with metal over its top, it must be bound together in a similar manner. This is illustrated in the mold for the marine cylinder, Fig. 97, in which both of these conditions occur.

If a casting has an internal flange requiring thickness of metal underneath the main core, the rigging will be altered to fit these conditions, as shown at D, Fig. 94. In this sketch *a* is a sticker plate and so will carry the loam necessary to face the bottom of the core. To this the small bearing plate *b* is securely bolted by the hook bolt *c*. This plate must set directly upon solid brickwork, as it carries the weight of the entire core. On this bearing plate are cast three studs which firmly support the sticker plate at the required height above the flange surface. The sticker plate carrying this print is filled with loam or dry sand and given a first baking, then swept to a finished surface before being inverted into position. Then the remainder of the core is built up on top and bound together as in the previous example. Another way to form the bottom of this core is to sweep up a dummy flange, *d*, in mud. Set the bearing plate *b* and work in the loam around the studs to form the short "neck" to the level of the top of the flange. Then spread over this flange ½ inch of loam and bed down onto this the sticker plate which has been previously filled with loam and dried, as will be described below. Be sure that the studs on *b* bring up to a firm bearing against the plate *a*, then clamp tight with hook bolts and proceed to sweep up the body of the core.

In case a cover plate must be bedded down against a flat surface, as in the example just mentioned, or must take the impression of an irregular surface on the top of a mold or pattern, as illustrated in Fig. 97, the method to pursue is as follows: After casting, invert the plate and carefully lower it into position and make sure that all fingers clear the surface by at least ½ or ¾ inch. Now set the plate with the fingers up, fill in with loam enough to just clear their tops, leaving the proper openings for runners, risers, tie bolts, etc., and dry thoroughly in the oven. Upon removal from the oven invert and try this loam cover again on the surface it must fit; scraping away any portions which project too much. Now hoist away the cover and coat the face with clay wash. Having previously prepared the surface of the pattern with oil and any loam joint with oil and parting sand, spread an even thickness of fresh loam all over and bed the plate down upon this. The cover plate being still hot will, by the aid of the clay wash, cause the thin layer of fresh loam to dry out and stick fast to the dry loam forming the body of the plate.

BUILDING A SIMPLE MOLD

As an example of a simple loam mold consider a large casting, having the shape of the frustrum of a cone, with a flange at the top and bottom and a flanged nozzle projecting from one side. The section is clearly shown in Fig. 96.

Set the sweep, level up building plate, and building the brickwork as shown in A, Fig. 94, sweep the seat, joint, and bottom surface of flange as shown at A, Fig. 95. The lower flange may be formed by a wooden pattern furnished by the pattern maker, but it is more common to have the sweep made with the small board *x*, which may be removed. By doing this the exact shape of the flange may be swept up without changing the main sweep, as shown at B, Fig. 95. This dummy flange, as it is called, is swept up from fairly stiff "mud." The next step is to seat the cope ring and set the cope sweep, as shown at C, Fig. 95. This sweep shapes the mold for the outside of the casting, for the top flange, and for the top joint of the mold. Loam is thrown, a handful at a time, against the joint and dummy flange, and the engaging faces of bricks rubbed with loam and pressed into position.

When the top of the lower flange is reached in this way, the courses are laid up for about two feet before the loam is spread upon their inner surface and struck off. This method is pursued until the mold is built to its full height.

The projecting nozzle is formed by a wooden pattern; this should be well oiled, and the brickwork and loam laid up under it to support it at the proper level, as given by the center line on the pattern and corresponding line on the sweep. Such projections frequently must be supported in exact position by temporary wooden framework or "skeleton" work until the mold is built up under them.

A finger *y* nailed to the top member of the cope sweep, shapes the guide surfaces on the outside of the mold which are used to center the cover plate in closing the mold. A similar finger exactly the same distance from the spindle, is fastened to the sweep used to form the cover plate.

After the finishing coat of slip has been swept on the surface of the cope, a joint surface about 4 inches wide is struck off flush with the outer face of the nozzle and that pattern is drawn out.

Then the whole cope is lifted off and set on iron supports where it may be conveniently finished with black wash and slicks. It is then baked over night in the oven

The dummy flange is now entirely removed from the first part swept, the core sweep is set, see D, Fig. 95, and the center core is struck up. This core is then blackened, slicked off and baked. The cover plate is struck off with the "stickers" up, and baked so. This cover carries six 1-inch round holes through it. These holes will be just over the shell of the metal when the mold is closed. Five of them connect with the pouring basin and serve as runners, while the sixth serves as a riser.

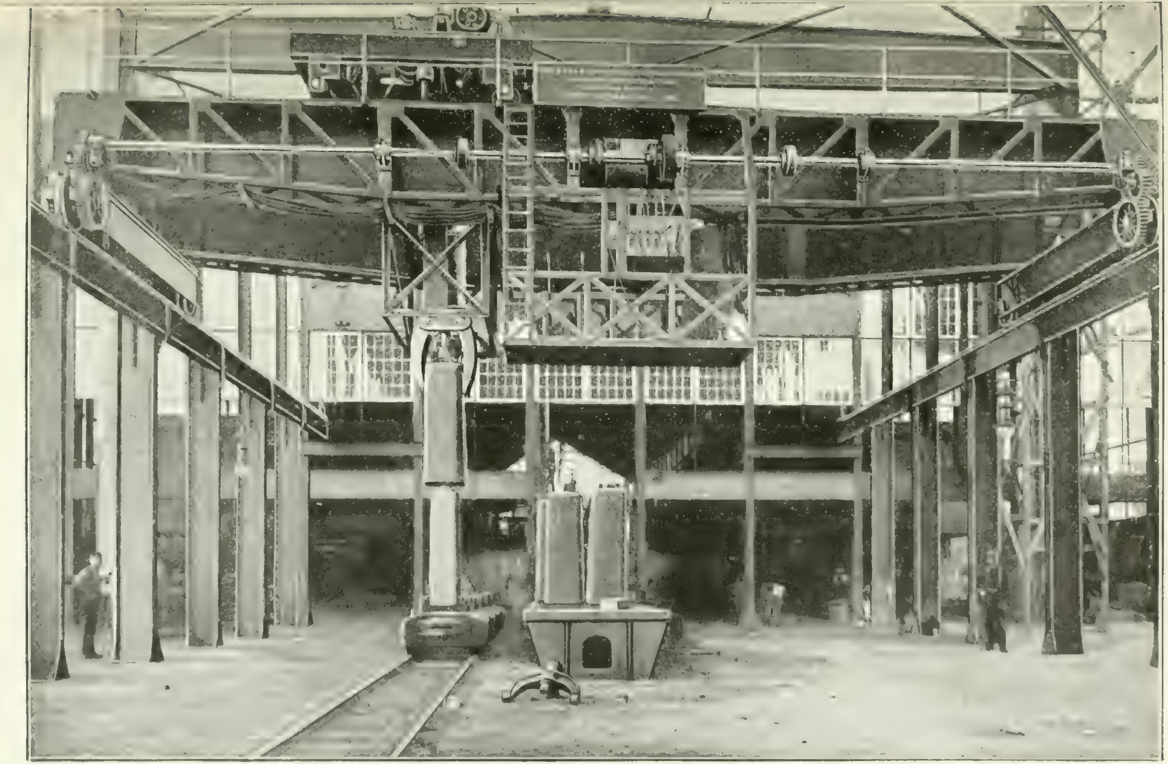
In assembling the mold for pouring, the core is first set on a level bed of sand, the cope is accurately closed over it by the aid of the guide marks, and lastly the cover plate is closed in position. Now the whole mold is firmly clamped by blocking under the spider, from which wrought iron loops or "strings" connect under the lugs of the building plate, as shown in Fig. 96.

The small core for the nozzle is now set, resting on stud chaplets. The cover plate D is slid over the end of this core and thus holds it firmly in position.

The casing is now placed around the mold and molding sand rammed in to support the bricks against the casting pressure. At the level of the nozzle core, cinders are placed and a pipe leads off to carry away the vent gases. The sand is rammed to about 12 inches over the cover plate and in it are cut the channels connecting the pouring basin and runners. A couple of bricks are set in the bottom of the basin to receive the first fall of metal from the ladle.

In pouring, the runners must be flooded at once and kept so until the mold is full.

In heavy cylindrical castings it was formerly thought necessary to carry the shell of the casting some 6 inches higher than the top flange. This "head" served to collect all dirt and slag that perchance entered



ELECTRIC INGOT STRIPPER.

The Wellman-Seaver-Morgan Co.

the mold with the iron. It was cut off in the machine shop and returned to the foundry as scrap.

With the increased knowledge of iron mixtures this head is now done away with in most instances.

Where a large casting is to finish practically all over, and very clean metal is therefore necessary, overflow channels, connecting with pig beds, are often constructed in modern practice. Then when pouring, the metal is not stopped until a certain percent of it has been flowed entirely through the mold. This of course tends to wash out any dirt which may have gotten into the mold when pouring began.

When the casting is cold the casing and packing sand are removed, as well as the blocking under the spider. Then the whole mold is carried to the cleaning shed where the bricks are removed and the casting cleaned.

BUILDING AN INTRICATE MOLD

As an example of a complex piece of loam work, let us consider the molding of a modern marine engine cylinder, as shown in section, Fig. 97. The example given is that of a double-ported low-pressure cylinder of a triple expansion type. In this case a full wooden pattern should be built, with core boxes for the various dry sand cores that enter into the construction of the mold.

The limits of this paper prevent our going into great detail in this matter; we will, therefore, confine ourselves mainly with an explanation of the drawing, Fig. 97. The heavy building plate has a spindle opening somewhat to one side of its middle to be under the center of the cylinder. Upon this building plate the foundation of the mold is swept, carrying the seat for the cope ring, the bottom face of the flange, and the seat for the main cylinder core. The cope ring No. 1 is made wide enough on one side to carry that part of the mold forming the steam chest. The main cylinder core No. 2, the construction of which has already been explained, is next swept up and lifted away, finished and baked. Now the cope ring is seated and the mold built and struck off for the bottom of the steam chest on a level with the bottom face of flange. Then the pattern may be set. Its position is accurately determined by the main cylinder print and the smaller prints of the steam chest which are bedded into the loam in accordance with measurements along a radial line marked off on the loam surface. With the pattern well oiled the cope is built to the height of the upper flange of cylinder; the entire back of the steam chest core print being left open. The top of the steam chest is lifted off with the draw-back No. 3, which joints at the middle of the upper steam nozzle, and carries that part of the mold to the level of the main cope joint. The two steam nozzles and the exhaust nozzle, may be made with separate cores as explained in D, Fig. 96. By using the draw-back the entire top of the chest core print is left open for convenience in setting the chest and port cores.

The top of the cylinder is jacketed, and through it pass the stuffing box and manhole openings. The flanges of these two openings connect and in the pattern are left loose. The whole top surface is so irregular that it requires three levels of sticker plates to mold it, aside from two small cover plates over flanges.

To the main cover No. 4-4-4-4 with its various length of fingers, is bolted a "crab" 5-5-5 to carry the loam below the flanges of the stuffing box and manhole; and below this again are hung the dry sand cores, No. 8-8-8, forming the jacketed part of the cylinder head. On top of the main cover is fastened a separate plate, No. 6, to shape the top of the upper steam inlet. And at No. 7 a plate with wrought iron bars cast along its edge carries the loam back of the steam chest flange. The small cover plates, No. 9 and No. 10, allow the flanges to be drawn for the parts which they mold.

The pattern is made in many parts so as to properly draw from the mold When this has been done, all mold surfaces are carefully blackened and slicked before baking.

While the mold proper is being built, the dry sand cores should be made up by the core makers, with the necessary rods, hangers, vent cinders, etc., as described under Core Making.

The manhole core, No. 11, is made with a stop-off piece in the box to give the proper angle at the bottom of the core It is hung to the cover and clears the main core by ½ inch. The stuffing box core rests in a print in the main cylinder core, and is held by a taper print in the cover plate, No. 10.

The jacket cores are hung as shown. The openings made in the loam above the crab, to allow the hook-bolts to be drawn up tight, are stopped off with green sand as previously described. The inlet cores No. 12-12, the exhaust core, No. 13, and the lightening cores, No. 14-14-14, are all bolted directly through the steam chest core, No. 15, to horizontal bars which are long enough to bear against the sides of the mold at the back. The upper inlet core, No. 12, is kept from lifting under the pouring strain by being bolted to the body of the main cylinder core. Stud chaplets are also set between the inlet and exhaust cores to ensure correct thickness of metal at these points.

The vent is taken off from the main cylinder core through the stuffing box core at the top. Sometimes a small ladle full of metal is poured through this opening when the piece is being poured to ensure lighting these gases. The vent for the series of port cores is taken off by ramming a cinder bed up the entire back of the steam chest core, allowing the gases to escape at the top. For safety, also, vents are taken from the bottom of the port and chest cores by the usual pipe vent.

The provision for pouring this mold requires especial attention. Notice the construction of the main basin, No. 16. The long runner, No. 17, leading to the bottom gate, is left open on one side when the mold is built so that it may be easily finished and kept free from dirt. Its open side is closed by cover cores when the mold is rammed up.

Ten or twelve small gates like No. 18 are connected by semicircular channels with the pouring basin, but so placed that no metal shall fall on a core. With the basin arranged as shown, the bottom part of the mold is first flooded with iron. When this has been done the metal is poured in faster so that hot iron is well distributed around the shell of the casting through the small top gates. Should the mold be poured at first from these top gates, the fall of the iron through the full height of the cylinder to the lower flange might result in "cutting" the loam on that surface.

Molds of this size are usually rammed in a pit so as to bring the pouring basin conveniently near the floor. The portion above the floor level is, of course, rammed inside a casing, as described in the previous example.

To guard against uneven cooling strains in this intricate casting the clamping pressure on the mold is relieved when the metal has solidified, but the sand is not removed from around the brickwork for several days. This allows very gradual even cooling.

It will be noticed that the piston does not work directly upon the inner walls of this type of cylinder. A separate hollow shell or lining is cast of strong, tough iron. This has outside horizontal ribs at top and bottom and middle, which are turned to fit correspondingly projecting ribs seen on the inside of the casting just under consideration. An air space is thus left between lining and main casting which forms a jacket around the bore of the cylinder.

MELTING

The subject of melting the metal which is to be poured into molds is one of the most important considerations in the foundry. It is also one which has received much attention in the last few years, the endeavor being to get away from the old rule-of-thumb methods and to arrive in the iron foundry at something near the precision in resulting metal that is already attained in the brass shops or the steel foundry.

The heat for all melting is obtained from practically the same two chemical elements namely, *carbon* and *oxygen*, carbon coming from the fuel, be it coal, coke, oil, or gas; and oxygen coming from the air of the blast.

The design of the furnace, the kind of fuel used, and the application of the blast, vary in accordance with the peculiar properties of the different metals and the degree of heat required to melt them.

The melting of steel and of copper alloys will be dealt with under separate headings. We shall now consider only the melting of foundry irons.

Foundry iron is melted in direct contact with the fuel in a *cupola furnace*. The name was derived from the resemblance of the furnace to the cupola formerly very common on the top of dwelling houses.

The cupola consists of a circular shell of boiler plate lined with a double thickness of fire brick and resting on a square bedplate with a central opening the size of the inside of the lining. This bottom is supported some $3\frac{1}{2}$ feet above a solid foundation, on four cast-iron legs. The bottom opening may be closed by cast-iron doors, which swing up into position, and are held so by an upright iron bar placed centrally under them. These doors, protected by a sand bed, support the charge during the heat, and "drop" it out of the furnace when all the iron has been melted. The legs curve outward and the doors are hinged as far back as possible to protect them as much as can be from the heat of this "drop." Several feet above the bottom, there is a door in the side of the stack, through which the stock is charged into the furnace. At one side, level with the bottom, is the *breast opening,* at which place the fire is lighted, and in which the *tap-hole* is formed for drawing off the melted metal. The spout, protected by a fire-sand mixture, projects in front of the breast and guides the metal into the ladles. Oblong openings called *tuyeres*, are placed about 12 inches above the bed, and connect with an air-tight wind-box which surrounds the outside of the stack near the base. The tuyères direct the blast into the fuel, increasing the heat sufficiently to melt the charge. Opposite each tuyère is an air-tight sliding gate with a peephole. This allows the melter to look directly into the furnace.

In the larger cupolas a second set of tuyères is arranged about 10 inches above the main ones. They are used when long heats are run off, to make up for loss of wind caused by the main tuyères becoming partially choked by slag. On cupolas over 36 inches inside lining, a *slag-hole* is provided. This is similar to the tap-hole, and is placed opposite the spout and about 2 inches lower than the main tuyères. Fig. 98 shows a section through a modern cupola furnace, and will need but little further explanation.

In lining the stack, the layer next the shell is usually made of boiler-arch brick about the size of regular fire brick. These are set on end, and should be fitted as tightly together as possible, and laid in a thin fire cement, made of very refractory fire clay and fine, sharp silica sand. The object is to fill every crevice with a highly refractory material. Specially made curved fire brick can be purchased for the inside lining, although some foundrymen use the arch brick for this lining as well. The lining over the tuyères is shaped to overhang them slightly, to prevent melted slag dropping into them during the heat. The lining burns out quickest about 22 inches above the tuyères at what is practically the melting zone. The angle shelves riveted to the shell (see cut) allow this section of the lining to be renewed without disturbing the rest of the stack.

The height of the tuyères above the bed varies with the class of work to be poured. Where the metal is tapped and kept running continuously and is taken away by hand ladles, as in stove-plate work, the tuyères are as low as 8 inches or 10 inches above the bed; while in shops where several tons of metal may be required to fill one mould, the tuyères are as high as 18 inches above the bed. The height of the spout above the molding floor also varies in the same way; for hand

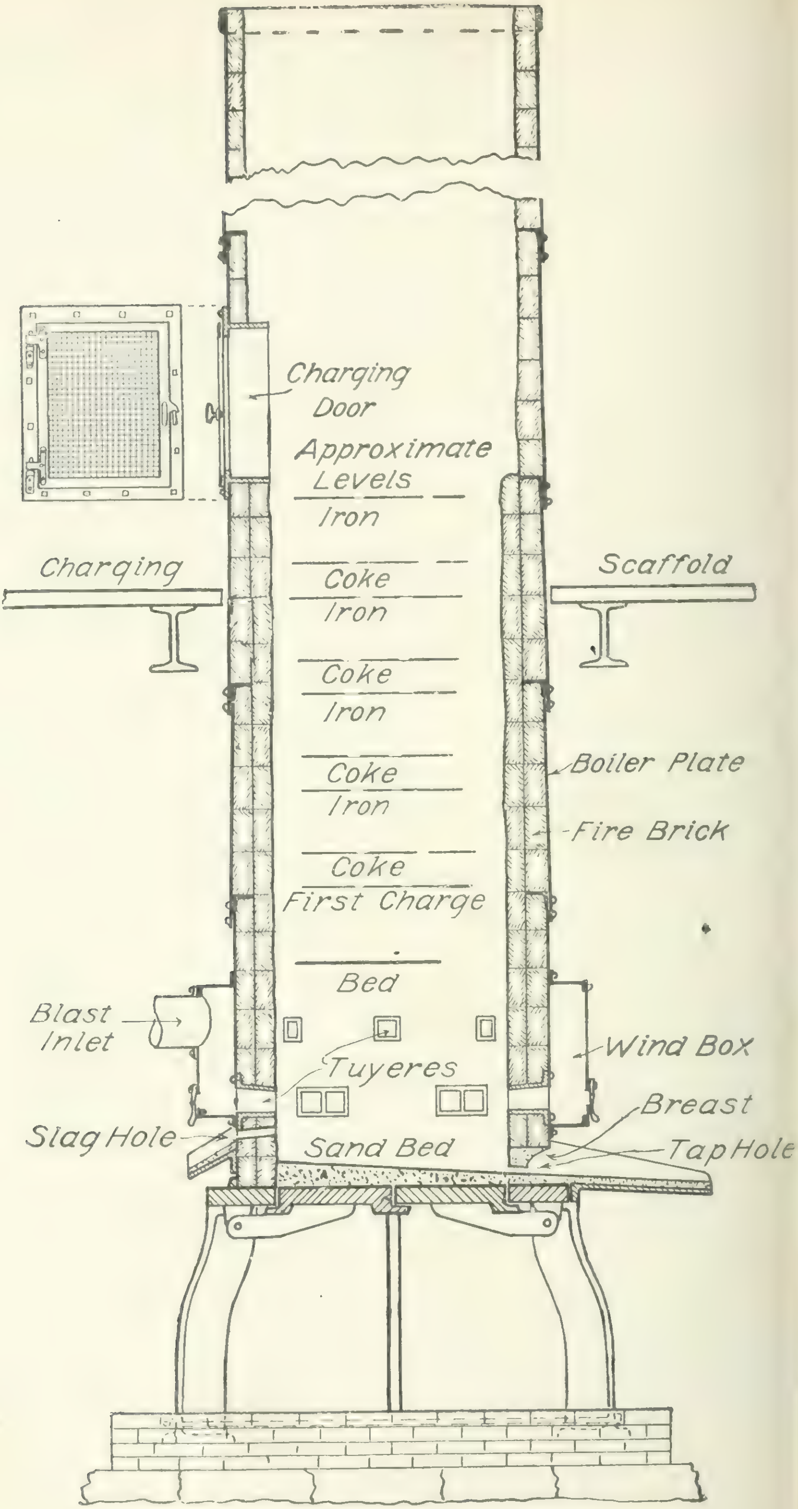


Fig. 98. Section Through Cupola Furnace.

ladle work it may be but 18 inches above the floor, while a height of 5 or 6 feet may be required to serve the largest crane ladles.

The accompanying table, prepared by Dr. Edwin Kirk, gives the approximate height and size of charging door and the practical melting capacity of cupolas of different diameters:

TABLE

Dimensions and Capacities of Cupola Furnaces

DIAMETER, INSIDE LINING Inches	HEIGHT OF CUPOLA Feet	SIZE OF CHARGING DOOR Inches	MELTING CAPACITY PER HOUR Tons	MELTING CAPACITY PER HEAT Tons
18	6- 7	15 x 18	[illegible]	1- 2
20	7- 8	18 x 20	[illegible]	2- 3
24	8- 9	20 x 24	1- 2	3- 5
30	9-12	24 x 24	2- 5	4-10
40	12-15	30 x 36	4- 8	8-20
50	15-18	30 x 40	6-14	15-40
60	16-20	30 x 45	8-16	25-60

A platform or *scaffold* is constructed at a convenient level below the charging door, and all stock is charged into the cupola from this platform. It should be at least large enough to store the stock for the first two charges of fuel and iron.

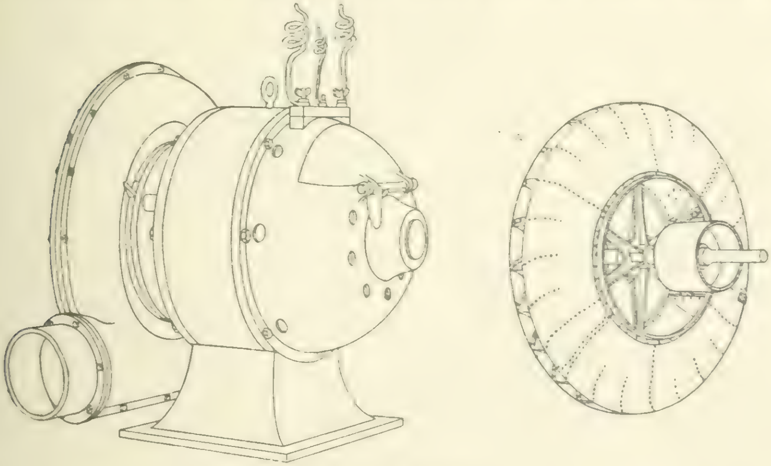


Fig. 99. Fan Blower.

Blast for the cupola is furnished by either a fan blower or a pressure blower. Fig. 99 shows a modern fan blower, the blast wheel for the same being shown at A. The high speed of the blades forces the air by centrifugal action, away from the center of the shaft. The casing is so designed that the blades "cut off" as it were at the top of the main outlet, the air being thus forced through the blast pipe. The current of air is continually being drawn into the fan through the central opening around the shaft.

An idea of the speeds at which blowers should run may be obtained from the following data: An 18-inch blower, at a speed of 4,100 revolutions per minute, gives 5 ounces pressure; a 24-inch at 3,750 revolutions per minute gives 6 ounces pressure; a 36-inch, at 2,900 revolutions per minute gives 10 ounces pressure; a 48-inch, at 2,600 revolutions per minute gives 14 ounces pressure.

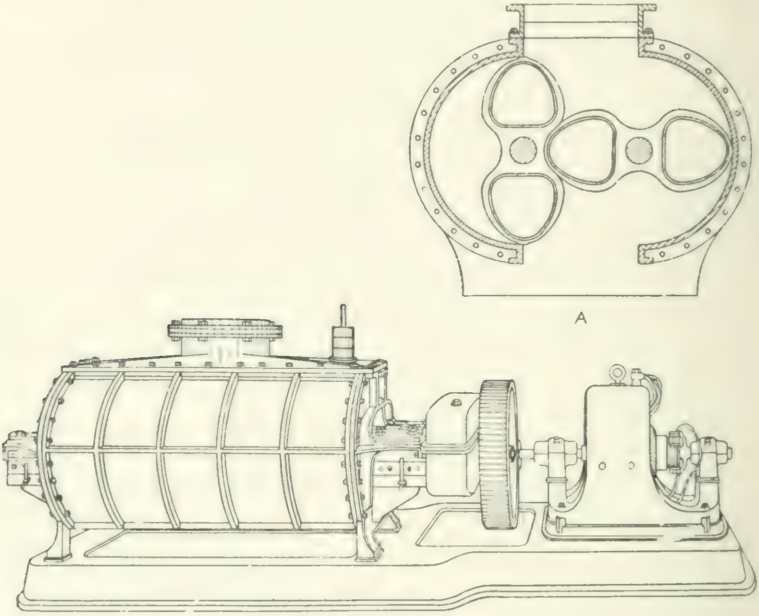


Fig. 100. Pressure Blower.

Since air is very elastic, and the pressure in this case depends entirely upon the centrifugal action of the blades, should the tuyères become clogged, the amount of air forced into the furnace will be reduced proportionately. On the other hand, it requires less power to operate the fan with reduced area of outlet than it does when the discharge is open free

In the pressure blower shown in Fig. 100, the action is positive, as will be seen from the sectional view (A, Fig. 100). The wipers mesh into each other in such a way that they entrap a quantity of air and force it out of the opening.

The full quantity of air is therefore forced through the tuyères at all times. In such case the power necessary to operate the blower increases as the tuyères become choked and the excessive force of the blast due to choked tuyères is hard on the lining of the cupola.

The cupola should have a blast-gauge attached to the wind-box to measure the pressure of air which enters the tuyères. The pressure should be sufficient to force the air into the middle of the cupola to insure complete combustion. The unit of air-pressure is one ounce. From 8 to 16 ounces is approximately the range usual in cupolas of from 48 inches to 70 inches inside lining.

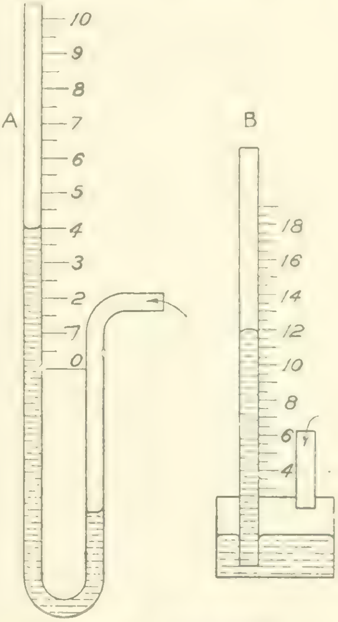


Fig. 101. Water Gauges

This pressure is measured by the displacement of water or mercury in a U-shaped tube. With both legs of the tube the same size as in Fig. 101, the graduations on leg A represent the pressure of double that height of liquid, as follows:

With *water:* 1.73 inches height = 1 oz. pressure; then graduations equal

$$\frac{1.735}{2} = .865 = \frac{55}{64} = \frac{7}{8} \text{ in.} - \frac{1}{64} \text{ in.}$$

With *mercury:* .127 inch height = 1 oz. pressure; then graduations equal

$$\frac{.127}{2} = .0635 \text{ in.} = \frac{1}{16} \text{ in.}$$

As this would be too small for practical use, mercury gauges are made with increased area exposed to blast pressure (see B, Fig. 101) and are graduated accordingly. (Review chapter on Pressure in Molds.)

OPERATING THE CUPOLA

The following routine must be pursued each time a heat is run off in the cupola:

Clear away dump from former heat.

Chip out the inside of furnace with special hand-pick, removing the lumps of slag which collect about the lower part of the cupola walls especially above the tuyères. Where the slag coating is comparatively smooth, do not touch it, as that is the best coating possible for the lining.

Daub up with a mixture of fire sand held together with about 1 to 4 fire clay, and wet with clay wash, to a consistency of thick mortar. Smear the surface to be repaired with clay wash; then, using the hands, plaster the daubing mixture into the broken spots in the lining, being careful to rub it in well, especially about the tuyères. The top of the tuyères should be kept slightly overhanging, for the reason already given.

The greater part of the daubing will be required from the bottom to level of melting zone, about 22 inches above tuyères.

Swing up bottom doors, and support by prop of gas pipe.

Build bottom; first cover doors with a 1-inch layer of gangway sand or fine cinders; then ram in burnt sand tempered about the same as for molds. This must be rammed evenly all over the bottom, and especially firm around the edges. Build the bottom higher at sides and back so that metal will flow toward spout. The pitch varies with size of cupola; 1 inch to the foot will answer for cupolas of 24 inches to 30 inches inside lining, while ½ that pitch will do for the larger furnaces.

The cupola bottom should be able to vent so that it will dry out quickly, and not cause the metal to "boil" before the furnace is tapped. It should be strong enough to hold its surface during the heat, but break and drop at once when the bottom is dropped. Too much pitch causes excess of pressure on the *bott*, making trouble in botting up; with too little pitch the metal will not drain well, causing a tendency to chill at the tap-hole. A little daubing mixture should be worked into the sand bottom just inside the tap-hole, to prevent breaking at this point when the tapping bar is forced through.

Lay the fire with shavings, just inside the breast; then fine kindling; then enough large kindling to make sure of lighting a layer of coke sufficient to form the bed. When the gases from the lower part of the bed burn up through, showing that the fuel is well lighted, *level up* bed with addition of a little more coke; and put on *first charge* of iron. Follow this with alternate charges of fuel and iron, to the level of charging door.

Form tap-hole; lay a bar of iron about $\frac{7}{8}$ inches round in the spout, projecting in through the breast opening; fill in breast around bar with a strong, loamy molding sand rammed hard. Recess this in well to leave actual tap-hole as short as possible.

Put on blast when ready for the metal, and leave tap-hole open. *Bott up* when the metal begins to run freely (generally about 7 minutes after blast is on). *Tap* when sufficient metal has collected to supply first ladles.

Bott clay should be mixed with about $\frac{1}{8}$ sawdust, to make it more fragile when tapping. This is made up in small balls, and shaped onto the end of the bott-stick (A, Fig. 102). The tapping bar B has simply a round taper point; C is a gouge or spoon-shape, useful for trimming sides of hole if bott does not entirely free itself when tapped.

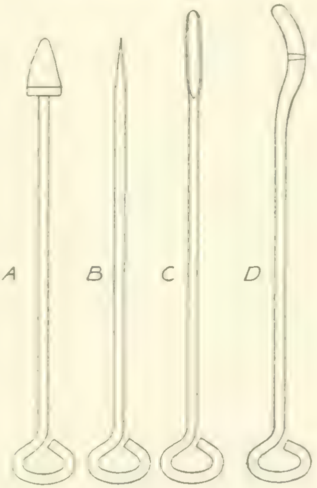


Fig. 102. Tapping Bars.

When all the iron has been melted, *drop the bottom*, by pulling away the bar that supports the bottom doors. Throw water on the dump, by bucket or hose, to deaden the heat, and leave it to cool off over night.

FOUNDRY LADLES

As the melted metal flows from the spout of the cupola, it is caught in ladles. The sizes of these are designated by the weight of metal they will hold; they vary from 30 pounds' to 20 tons' capacity. The names of ladles relate to the method of carrying them. The accompanying table, containing references to accompanying cuts, gives compact data regarding foundry ladles:

TABLE

Data Regarding Foundry Ladles

TYPE OF LADLE	HOW MANAGED	CAPACITY (pounds)	SIZE (inches)			WEIGHT OF LADLE
			Top	Depth	Bott'm	
			Thickness for Lining			
Hand Ladle A, Fig. 103	Hand shank	30-50	7-8 ¾	7-8 Side ½	6-7 ½-¾	15-16 lbs.
Bull Ladle B and C, Fig. 103	Single or double shank	80-350	9-15 1¼	9-15 ½-⅝	8-13 ¾-1	35-100
Crane or Trolley Ladle Like C, with bail	Bail with single or double shank	300-2,000	14-26 1¾	14-26 ⅝-1	12-23 1-3	115-350
Geared Crane Ladle Fig. 104	Worm gear on heavy bail	1,000-35,000	20-75 2-4	20-60 1-4½	18-66 1½-5	1,900-7,000

In the three columns under "Size," the larger figures give the dimensions inside of ladle shells. The smaller figures refer to the thickness of the lining at the top, sides, and bottom of the ladles.

Hand ladles are made of cast iron or pressed steel. The larger ladles are built up of boiler plate. Cast iron is poured from the top of the ladle, which should therefore be provided with lips. Ladles must be lined to protect them from burning through. Up to one ton capacity, the cupola daubing mixture is used. The bowl is smeared with thick clay wash, and the clay pressed in hard with the hands, being rubbed smooth on the inside. The lining should be kept as thin as possible, ⅝ to ¾ inch on hand-ladles, 1 inch to 1½ inches on large ones; the bottom lining from ⅓ to ½ thicker than sides, as it receives the first fall of the incoming metal.

The larger ladles are first lined with fire brick of thickness proportionate to their size, and then daubed on inside with clay mixture similar to cupola lining. The lining must be well dried before use, to drive out moisture. In stove-plate and hardware shops, where most of the pouring is done with hand ladles, a special ladle-drying stove similar to a shallow core oven is provided. A wood fire is built inside of the larger ladles to dry them out. To preserve a lining as long as possible, slight breaks are repaired daily. As with the cupola, the slag formed by the hot metal forms the best coating possible for inside lining.

POURING

The first thing to be considered here is skimming off the slag which collects on top of the metal. This should be done on larger ladles before leaving cupola, and again while metal is being poured. For this, a long iron rod is used, with blade shaped as in D, Fig. 102. This is rested across top of ladle near lip, and effectively holds the slag back; the long handle permits the skimmer to stand well back from the heat of the metal. On small ladles, skimmers are of course shorter, and the end is bent up more for convenience, as the ladles will be much nearer the floor when pouring with them..

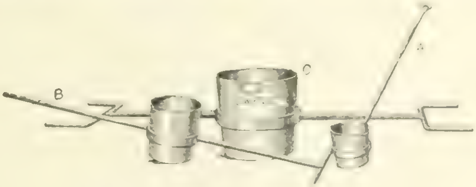


Fig. 103. Hand and Bull Ladles.

Hand and bull ladles are shown in Fig. 103, while Fig. 104 shows a crane ladle.

Much skill is required in pouring a mold. A molder must know the character of the work, and judge whether it must be poured fast or slow. In general, light work cannot be poured too fast. Heavier work is poured more slowly. Care must be exercised to keep the stream steady from the first, and not *spill* into the mold, as this may

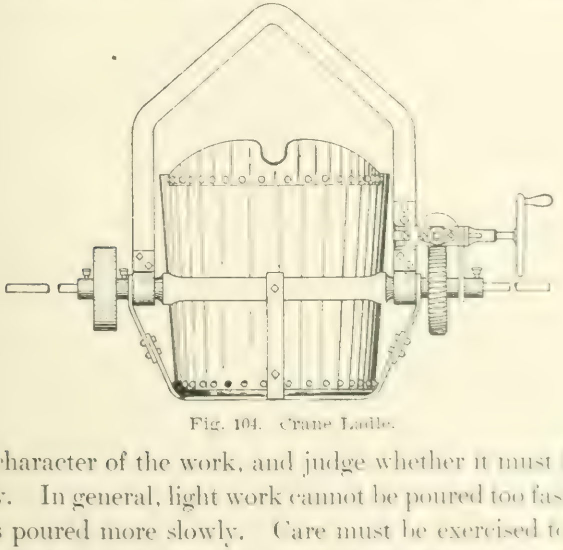


Fig. 104. Crane Ladle.

cause "cold shuts" or leave "shot" iron in the castings. The runner basin must be kept full, for gates and runners are made with this express purpose in view, as has been stated previously.

Metal must not be allowed to chill or "freeze" in the ladle, as this would destroy the lining when it came to removing the cold metal. Metal left in the ladles when the mold is full, must be poured back into a larger ladle or emptied into a convenient pig bed. These are built in a sand bed usually near the cupola, or stout cast-iron pig troughs or chills are provided. They should taper well on the inside, holding about 50 pounds each. Some are arranged to swing on trunnions for convenience in dumping. They should be smeared with a heavy oil and dusted with graphite, to prevent the metal sticking in them. It is safer to heat these pig molds as well, so that no moisture will form and cause a "kick" or explosion when hot metal is first poured into them.

CUPOLA MIXTURES

By this term is meant the proportioning of the various pig irons and scrap that make up cupola charges, with the object of obtaining definite physical and chemical properties in the resulting castings.

The requirements of castings vary; and metal that would be good if run into thin stove-plate, would be entirely too soft for heavy machine castings. Again, iron that might answer all requirements of a bed plate would not be strong and tough enough for steam cylinder work. The one in charge of this work, therefore, must so mix the different irons that his castings shall be soft enough to machine well if necessary, and at the same time be hard enough to stand the wear and tear of use.

Formerly the appearance of the fracture of a pig or scrap was the sole guide in determining mixtures. Unquestionably the fracture of iron indicates to the experienced eye much as to its physical properties. But this method of mixing has repeatedly proved misleading.

Representative practice to-day recognizes chemical analysis of the various irons as most essential to the proper mixing. Many firms now buy their pig iron, and many other allied supplies, by specification; and the chemical analysis of the iron must show that its various metalloids come within certain limited per cents.

To understand, then, these modern methods, we must consider the subject of the chemistry of iron.

CHEMISTRY OF IRON

An element, in chemistry, is a form of matter which cannot be decomposed, or, in other words, cannot be broken up into other forms by any means known to science.

Iron is such an element; but absolutely pure iron is of no commercial value; it is only when it is combined with impurities—or, as we must recognize them, other chemical elements—that mankind is interested in it.

In the forms of iron with which we are dealing, pig iron and cast iron, five elements are considered as affecting their physical properties. These elements are Carbon, Silicon, Sulphur, Phosphorus, and Manganese.

Carbon is the most important and most abundant of all the chemical elements. It forms the principal part of many substances in daily use about us, such as coal, coke, lead pencils, graphite facings, etc. In its relation to iron, it is peculiar in that it occurs in iron in two forms. One is in a chemical combination forming a hard substance with a fine grain, of which tool steel is the purest type. The other is simply a mechanical mixture forming minute facets of free carbon interposed between the crystals of the combined form. It softens cast iron, but weakens it by causing larger crystals to form. Drawing the finger across a freshly cut surface or fracture of cast iron, some of this free carbon will be rubbed off, and will show as dirt on the finger. We shall use the term *graphite* in referring to this form of free carbon, and the term *combined carbon* in referring to the element in its combined state.

Silicon of itself is a hardening element in cast iron, but on account of its marked influence upon carbon formations, it is usually considered a softener. During the cooling process, silicon retards the formation of combined carbon, thus increasing the formation of graphite in proportion to the increase of silicon. At the same time, through its own influence on iron, it preserves the fine character of the grain, and so maintains the strength of the casting. In other words, within certain limits, the addition of silicon softens castings without impairing their strength. It makes iron run more fluid, and reduces shrinkage. Silicon varies in castings from 1.50 to 2.50 per cent.

Sulphur is the most injurious element in iron. It makes castings hard, red-short, and tends to the formation of blow holes. At the melting temperature, iron will absorb sulphur from the fuel—a decided reason why foundry coke should be as free as possible from this element. Sulphur in castings should not exceed .07 per cent.

Phosphorus tends to make iron run very fluid when melted. It is a hardener. For machine castings it should not exceed 1 per cent.

Manganese strengthens, and of itself hardens iron. Chemists are beginning to consider its proportions more carefully, in the belief that under certain conditions it acts as does silicon, softening the castings while retaining their strength. It is usual to keep it below .5 per cent.

The strength of a casting and the finish which it is capable of taking, are largely dependent upon its having a fine, even grain. We have seen that the proportions between the combined carbon, the graphite, and the silicon have decided influence upon this condition. But the rate of cooling must also be taken into account. A thin casting cools rapidly, tends to increase the combined carbon, and without the influence of silicon would be hard and brittle. In a heavy casting, the metal stays liquid longer, more graphite is thrown off, and the casting is naturally softer.

Therefore light work requires a larger proportion of silicon to counteract the effect of the rapid cooling than does larger work.

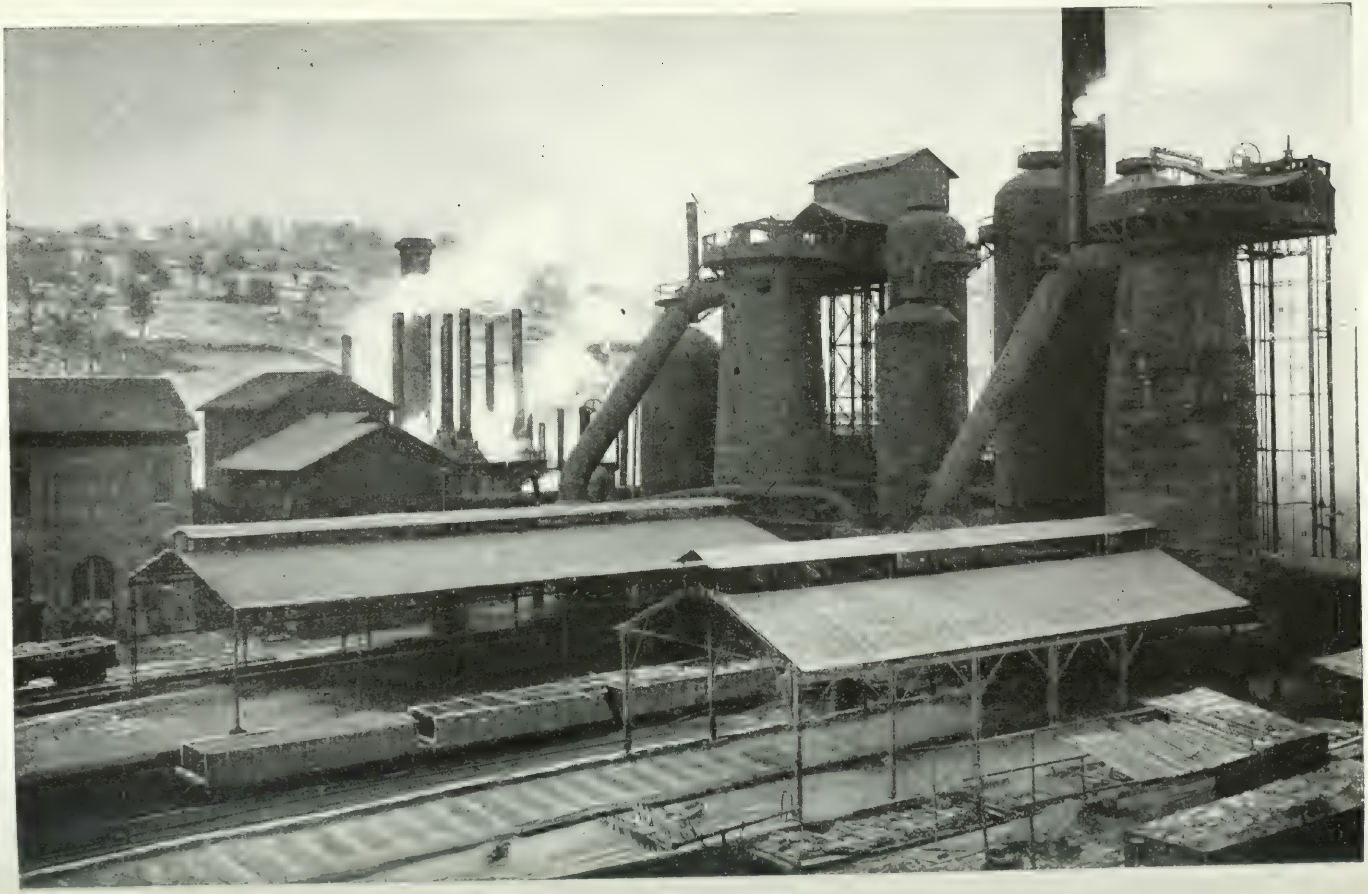
Modern practice makes daily analysis for the two carbons, the silicon, and the sulphur, occasionally testing for the other elements to see that they are kept within their safe limits. Silicon, however, is used as the guide for regulating mixtures. The following shows good proportions of silicon for different classes of work:

Steam cylinders	1.70 per cent
Medium heavy work (½ inch to 2 inches thickness)	2.0 " "
Light work (less than ½ inch thickness)	2.50 " "

A more complete analysis of results to be aimed for is:

	Si.	P	S.	Mn.
Automobile cylinders	2.25	1.	.075	.5 per cent
Corliss engine cylinders (1¼ to 1½ inches thickness)	1.20 1.70	Below .1	Below .095	" "

To calculate for any result, we must first know the analysis of the irons to be used in making the charge. We shall consider silicon as the guide.



With a firm keeping track of results, the proportion of silicon in their "home" scrap can be accurately estimated. With miscellaneous machinery scrap, this is more difficult. The following, however, are safe estimates:

Small, thin scrap	2 –2.4	per cent
Large scrap ranges	1.50–2	" "

The analysis of pig iron is made from drillings taken from a fresh fracture. Between the very fine grain about the chilled sides of the pig, and the very coarse grain in the center, average-sized crystals will be noticed in the fracture. It is here that the drillings for analysis should be made, as indicated in Fig. 105. About a ¾-inch flat drill is best to use, as it cuts a more uniform chip from the varying grade of pig than does a twist drill.

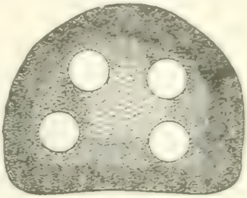


Fig. 105. Analysis Section.

To determine the analysis of a carload lot of pig iron, the following method is employed. Select ten pigs which will represent an average of the close, medium, and coarse-grained iron in the car. These pigs should be broken, and drillings taken from the fresh fracture. The drillings from these ten fractures are thoroughly mixed together, and about two ounces by weight, or a large tablespoonful by measure, is sufficient for the chemical analysis. The result is taken for the average analysis of the carload.

The smaller foundries who do not employ a chemist can get a good working analysis of their iron from the furnace from which it is bought. Or, in many cases, sample drillings are sent to a practicing chemist.

The proportions of silicon and sulphur contained in the ordinary grades of pig iron are approximately as follows:

GRADE	SILICON	SULPHUR
Ferro-silicon	7 –12 per cent	.03 per cent
Silvery	3 – 5 " "	.03 " "
No. 1 Foundry	2.50– 2.90 " "	.03 " "
No. 2 "	1.95 – 2.40 " "	.04 " "
No. 3 "	1.40– 1.90 " "	.05 " "

When we have the analysis of our iron, we can proceed to calculate the mixture, bearing in mind that some of the silicon will be burned out of the iron during the heat. From .15 to .25 per cent is a fair estimate for this loss in cupolas ranging from 36 inches to 72 inches inside lining. This loss must be deducted from the final estimate.

It is proposed to make a mixture, using three of the following irons, for miscellaneous machinery castings which require about 2 per cent silicon. And we wish to use one-half scrap:

Silvery	4 per cent
No. 1 Foundry	2.65 " "
No. 2 "	2.22 " "
No. 3 "	1.75 " "
Scrap "	2.00 " "

The student should bear in mind that the sign of *per cent* means $\frac{1}{100} = .01$. To multiply a whole number by per cent, set the point two places to the left; thus 35 per cent of 5,000 = .35 × 5,000 = 1,750.

To multiply per cent by per cent, set each point one place to the left before multiplying and the result may be expressed as per cent; thus 25 % of 35 % = 2.5 × 3.5 = 8.75 per cent.

Then we have:

A	B	C	D
No. 1	25. %	× 2.65 % =	.6625 %
No. 2	20. %	× 2.22 % =	.4440 %
No. 3	5. %	× 1.75 % =	.0875 %
Scrap	50. %	× 2.00 % =	1.0000 %

Total, 100. % of charge has 2.194 % Silicon content.
Deducting for loss in heat .20 %
1.994 % Estimated silicon in result.

Or, with a No. 2 iron and Silvery:

A	B	C	D
No. 2	45. %	× 2.22 % =	.999 %
Silvery	5. %	× 4.00 % =	.200 %
Scrap	50. %	× 2.00 % =	1.000 %

Total, 100. % of charge has 2.199 % Silicon content.
Deducting for loss in heat .17
2.029 % Estimated silicon in result.

In these examples, column A is the kind of iron; B, per cent of this iron used in charge: C, per cent of silicon in single grade of iron: D, per cent of silicon to whole charge as supplied by each grade.

One or more per cents in column B are usually decided upon before beginning calculations, and then the others are varied until the desired silicon content is obtained.

With this as a guide, it is a simple matter to find the actual weight for each grade, to make up any size of charge. For example, we wish to put 5,000 lbs. on bed and 3,000 lbs. on other charges, using first mixture:

From column B.		Bed.	Other charges.
No. 1	25 % × 5,000	1,250 lbs.	750 lbs.
No. 2	20 % × 5,000	1,000 "	600 "
No. 3	5 % × 5,000	250 "	150 "
Scrap	50 % × 5,000	2,500 "	1,500 "
		5,000 lbs.	3,000 lbs.

PRINCIPLES OF MELTING

Combustion cannot take place without oxygen, of which the air is the most abundant source of supply. For example, in the incandescent electric light, a strip of carbon is heated to a white heat; but it does not consume, or burn up, because all air has been exhausted from within the globe.

In the cupola furnace, both coal and coke are used as fuel. They consist largely of carbon, and, after being lighted by the kindlings, are kept at a glowing red heat by the natural draft through the open tuyères. The blast supplies the oxygen necessary for a melting heat. The quantity of air forced in by the blast cannot be entirely taken up by the layers of fuel immediately above the tuyères; thus complete combustion does not take place until a distance of 18 to 23 inches above the tuyères is reached. This is termed the *melting zone*. It is the aim of the melter to keep the top of his bed as nearly as possible at this level, so that the iron resting on it shall be exposed to this intense heat and melt rapidly.

As the fuel of the bed burns away, this level tends to be lowered. But the iron on top of it melts, and drops to the bottom of the cupola; and the subsequent charge of coke restores the level of the bed for the next charge of iron; and so on.

FUEL

Both anthracite coal and foundry coke are used in the cupola. Coal, owing to its density, will carry a heavier load than coke, but it requires greater blast pressure, and will not melt as fast as coke. Coke, for foundry use, should be what is known as "72-hour" coke, as free as possible from dust and cinders. Coke is made up of a sponge-like "coke" structure which is almost pure fixed carbon, and an open, "cellular" structure which makes it especially valuable as a furnace fuel because it is so readily penetrated by the blast.

A representative analysis of a strong 72-hour coke is as follows:

Moisture	.49	per cent
Volatile matter	1.31	" "
Fixed carbon	87.46	" "
Sulphur	.72	" "
Ash	10.02	" "
Cellular structure	50.04	per cent
Coke structure	49.96	" "
Specific gravity	1.89	
Heat units per pound	12,937	

FUEL TO IRON

The proportions of the bed fuel, first charge of iron, and subsequent charges of fuel and iron, vary greatly with the size and design of the cupola, the grade of fuel used, and the method of charging.

To determine the right amount of fuel for the bed, the most practical thing to do is to "cut and try," especially with a new equipment.

For a 36 to 48-inch cupola, average 22 inches above the tuyères, with a 10-ounce blast to start with, the best way to proceed is to chalk off this distance inside the cupola before daubing up. Then, from a $\frac{1}{2}$-inch rod of iron, bend a shape like Fig. 106. The distance *a* equals the distance from the mark inside cupola to about 4 inches above bottom of charging door. When the coke is well lighted, before charging the iron, level off bed according to this gauge. The safe side is to have the bed too high. If the bed is too high, it will show by slow but hot metal; if too low, the metal will be dull. After first heat, the height may be adjusted until proper melting is obtained; then try always to work to same height. The weight and character of the coke charged on the bed should be carefully noted

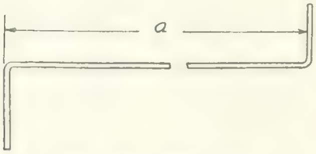


Fig. 106. Bed Gauge.

No fixed rule for general application can be given for proportioning the alternate charges of iron and fuel. From 4 to 6 pounds of iron may be melted to one of heavy coke on the bed; about $\frac{1}{3}$ less, for light coke.

Intermediate charges of coke should be just sufficient to preserve the upper level of the bed. The layer will usually be about 6 inches thick. Its weight should be carefully taken.

Subsequent charges of iron may be made 8 or 10 pounds to one pound of coke put between charges.

The action of the furnace must be carefully watched, with the aim to make it melt the iron charged as rapidly as possible and bring it down white hot. Also, bring the ratio of iron to fuel as low as may be, without sacrificing either of these other objects.

SAND MIXING

When a mold is poured, the intense heat of the iron burns out those properties in the sand which give it its bond, making it necessary that a certain proportion of new sand shall be mixed with the heap sand and used as facing. See explanation in earlier paragraphs.

The facing sand should be mixed daily for the molders by one or more of the laborers, at a place convenient to the storage sheds and molding floors. A hard, smooth floor of clay or of iron plates is a great advantage.

The proportions of the different sands are measured by shovel, bucket, or barrowful, and spread over each other in flat layers, sufficient water being sprinkled on to temper the pile. The sand is then cut through once with the shovel, then put through a No. 2 sieve, all lumps being broken up and refuse thrown out. It is next put through a No. 4 sieve, and thrown in a pile ready for use.

When this work is done by hand, the ordinary screen sieve commonly employed by masons is used for the riddling, and a round foundry riddle for the final sifting. To reduce the labor of this, the

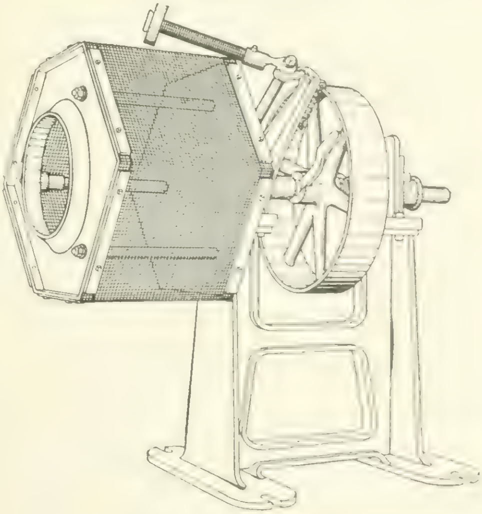


Fig. 107. Rotary Sieve.

riddle is slid back and forth on a pair of parallel bars supported conveniently above the storage pile.

There are two classes of labor-saving machines used in mixing facings, core sand, etc.—those which mix by riddling, and those which mix by a combined breaking and stirring action. There is great variety in the styles of these machines on the market. The illustrations show the typical mechanical devices in use.

Fig. 107 is made with wire on one or both ends, and is driven by belt or connected motor. Sand shoveled into the central opening is sifted in a pile on floor, or direct into barrow. The rubber hammer on top automatically raps each face of sieve as it revolves, knocking the meshes free from sand.

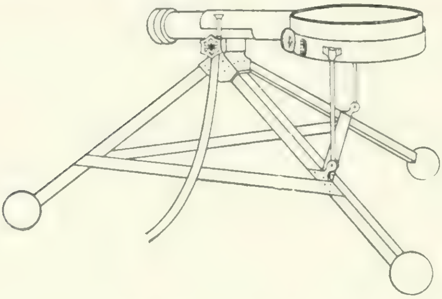


Fig. 108. Sand Shaker.

Fig. 108 shows one of the latest labor savers in this line. Here a foundry riddle is supported in a metal ring attached to the piston of the machine. It is made to vibrate rapidly by means of compressed air or steam. These shakers are made with portable tripod, as shown; they are also made stationary or are fastened on a post by means of a swivel joint, to be swung

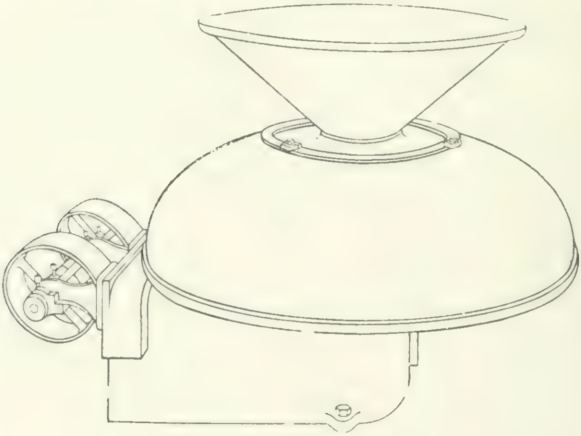


Fig. 109. Centrifugal Mixer.

over a wheelbarrow or over a molding machine, and out of the way again when not in use.

Fig. 109 shows a centrifugal mixer. Inside of the umbrella casing a horizontal plate about 12 inches in diameter and carrying a number of vertical steel pin about 6 inches long, is fastened to the top of a short upright shaft driven by a belt running inside of the casing shown at the base of the machine. The machine runs about 1,500 R. P. M.; and sand shoveled into the hopper is very evenly broken up by the pins and thrown against the steel hood, breaking and shattering any lumps of clay or loam and making a very uniform mixture. The hopper may easily be removed to clean the plate. The machine is used for the final mixing.

Fig. 110 shows a foundry grinder or facing mill. It is the type of mill used for mixing loam. Either the pan or the rollers are attached to the driving shaft and made to revolve, crushing and mixing whatever is shoveled into the pan. Frequently, a stout blade, something like a plowshare, is fixed between the rollers, and prevents the mixture caking to the bottom of the pan. The faces of the rolls are of very hard or of chilled cast iron to withstand wear.

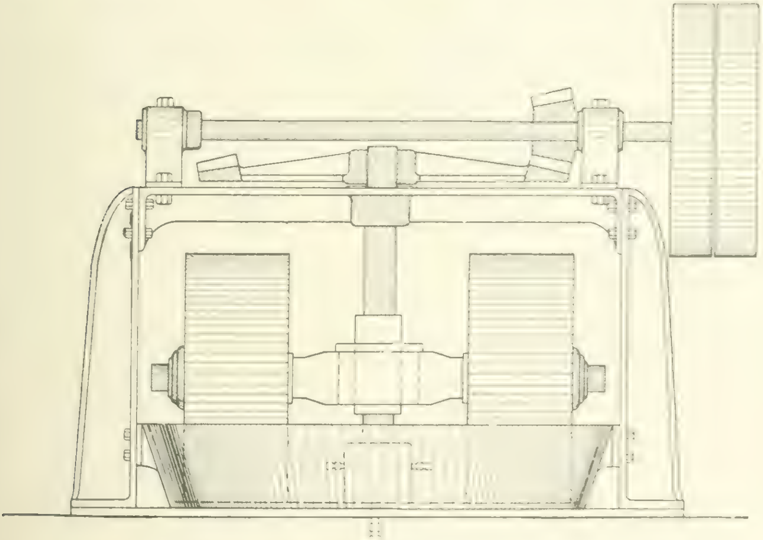


Fig. 110. Facing Grinder.

When the loam mixture is sufficiently ground, it must be shoveled from the pan, and delivered to the molders or stored temporarily. It will "set" if stored too long.

This is the type of mill used in the steel foundries, for grinding the facing materials. The various sands are dumped into the pan at one side, and, when ground sufficiently, are shoveled directly from the pan into a centrifugal mixer. This prepares them for use.

CLEANING CASTINGS

After a casting has solidified in the mold, the flask should be removed, leaving the casting in the sand. For light bench work and snap flask work, the mold is lifted bodily and the sand dumped on the pile, the bottom boards piled in one place, and the cases piled in another ready for the next day's work. As the molds are dumped, the castings are removed from the sand and piled at edge of gangway. When all castings have been removed from the sand, the gates are broken and thrown in a pile by themselves. When cold enough to handle, the castings are removed to the cleaning room, and the gates and sprues to the scrap pile. With heavier floor work, the clamps are removed as soon as the casting has set; the flask is rapped with a sledge hammer and stripped off the mold, leaving the castings to cool gradually in the sand. Sometimes a sharp blow is given on top of the runner while it is still red; this breaks it off before the flask is shaken out. At a red heat, cast iron is very weak and can easily be broken.

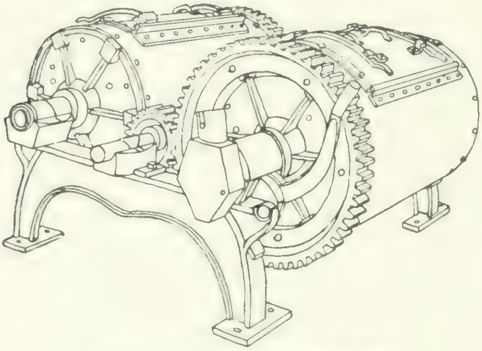


Fig. 111. Dustless Tumbling Barrel.

The most effective way to clean small castings is in a rattling barrel. Fig. 111 shows a modern set of dustless barrels. The shell of the barrel is $\frac{5}{8}$-inch boiler plate riveted to cast-iron heads, with a door arranged to be entirely removed for packing and dumping. The bearings are hollow, and from one end the dust is drawn off through a galvanized iron pipe. This pipe connects with an air-tight wooden chamber (Fig. 112) varying in size with the number of barrels connected with it. In this chamber hang a number of cloth-covered screens. An exhaust fan is connected to this chamber at the opposite end from the inlet pipe.

When the fan is in operation, a strong current of air is drawn through the barrels and through the chamber. The dust, entering the chamber, settles on the screens, so that but little dust escapes to the outside air.

When necessary, the exhaust is stopped, and, by means of a crank on the outside of the dust chamber, the screens are shaken and the dust drops off, when it can be removed through a trap into an ash can or wheelbarrow.

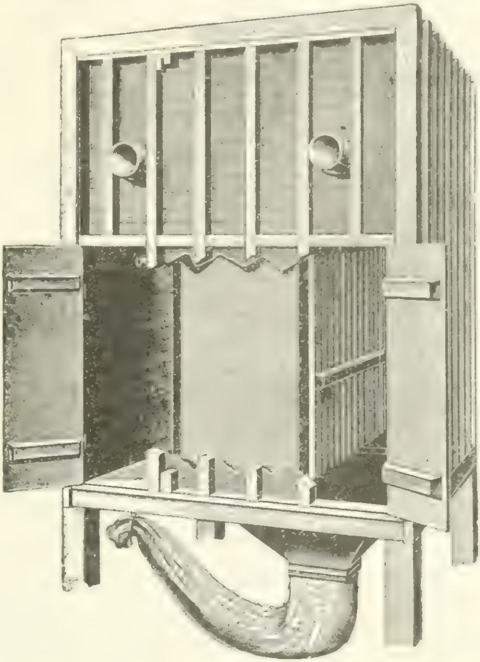


Fig. 112. Dust Collector for Tumbling Barrel.

The driving shaft carrying the pinion revolves all the time, and any barrel may be thrown over into gear or drawn out of gear by the operation of a hand lever. The barrels should run about 25 R. P. M. Each barrel should be packed as full as possible with several shovelfuls of gates, shot iron, or hardened stars thrown in with the castings. The cleaning is accomplished in from twenty minutes to half an hour by the scouring action of castings, scrape, etc., rubbing against one another. Castings up to 50 or 100 pounds can be rattled but only those of a similar character as to design or weight should be packed in together; otherwise the lighter castings will be broken by the heavier. When removed from the barrel, the work should show a smooth, clean surface of an even gray color.

From the rattlers, castings go to the grinding room, where projecting gates or other slight roughness is removed on the emery wheel.

Heavy castings are cleaned by hand, by pickling, or by sand blast.

When cleaning by hand, the worst of the sand is rapped off by light hammering, the remainder scraped off with old files and steel wire brushes (Fig. 113, A). Some shops rub off finally with broken pieces of coarse emery wheel. Risers and fins are removed with cold chisels. The pneumatic chisel shown in Fig. 113, B, is used as a time-saver. Where work is light enough to handle, small fins are removed by emery wheels; medium coarse wheels will cut faster on cast iron than fine ones, and will hold their shape better.

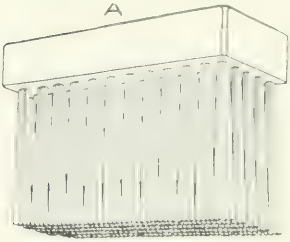


Fig. 113 A. Steel Bristle Brush.

It is when castings must be cleaned by hand, that value of a good facing dust shows itself. With the proper facing, the sand cleaves readily from the casting, leaving a fine-looking, smooth surface. With poor facings, on the other hand, the iron burns into the sand, making it hard to clean, and leaves a rough surface on the work.

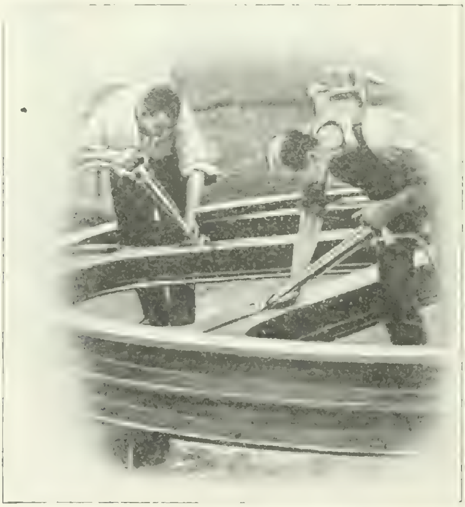


Fig. 113 B. Pneumatic Chisel

Pickling is a method of cleaning resorted to where there is much machining to be done on a casting. The work is placed in a pile on a suitable platform, and dilute sulphuric acid is thrown over it during one day, frequently enough to keep it well wet. The platform should be arranged to drain the acid back into the vat. Acid is diluted from 1 to 8, to 1 to 10. After about 12 hours' bath with acid, the castings are washed clean with hot water. The acid acts on the hard skin of oxide of iron, which forms when the iron strikes the damp sand, and eats through this skin to the iron itself.

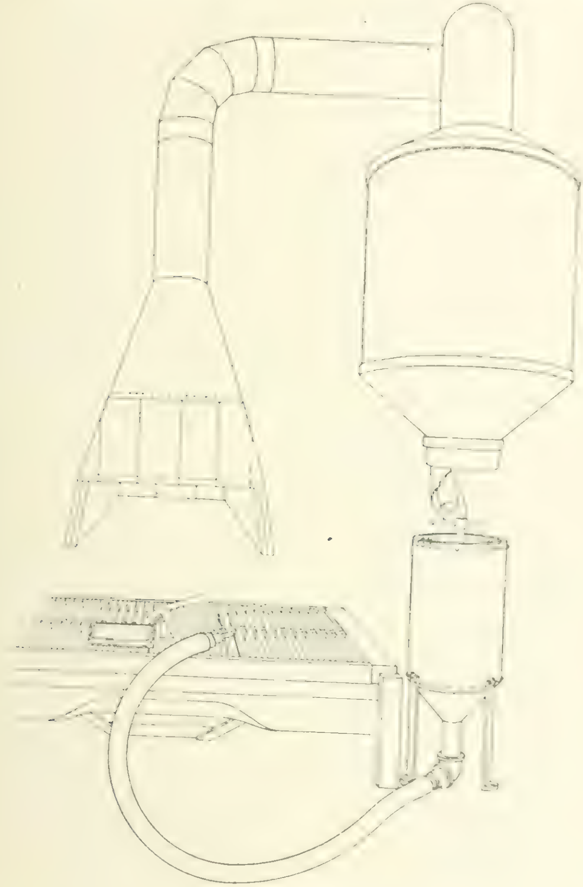


Fig. 114. Sand Blast.

The washing water should be hot enough to warm the castings sufficiently for them to dry rapidly without rusting. The acid must be thoroughly washed off, or it will continue to eat into the iron and cause a white powder (sulphate of iron) to form on the surface.

An excellent arrangement for a pickling department is to have the "trough" arranged on skids which will allow it to be rocked endwise. This will drain into the pickle vat when acid is being thrown on, and drain to the gutter when the castings are being washed. Sheet lead is the best protective covering for small pickle troughs, but it is expensive and not durable enough to stand for heavy work.

For castings of such shape and size that they cannot well be rattled, but are too small to be cleaned by hand, the sand blast has been used to advantage in many shops.

Fig. 114 gives an idea of the arrangement of the cleaning stall. Castings are placed on the wooden grating. By means of compressed air, a sharp silica sand is forced through a strong rubber hose and directed against the castings. The nozzle is of hardened steel. The operator wears a helmet supplied with fresh air by an air-hose, to protect his eyes and lungs from the clouds of fine dust. An exhaust hood is arranged also to take off as much of the dust as possible.

The manual labor of this method is practically reduced to nothing, aside from handling the castings. The system, however, requires the installation of a rather considerable equipment, which has debarred its use in many foundries.

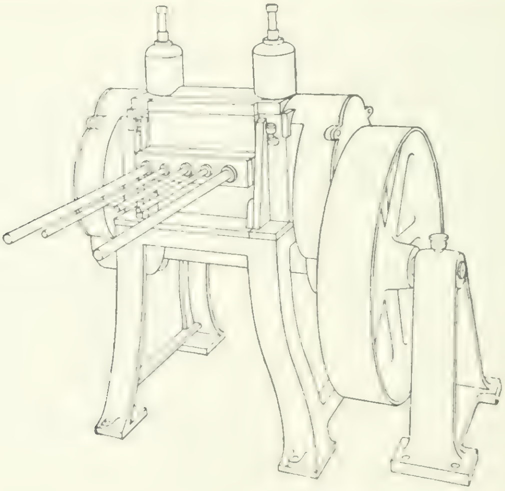


Fig. 115. Core Rod Straighteners.

In removing cores, the bars become very much bent. In such shape they were formerly scraped or refitted to suit new cores, with a hammer and block of iron. Fig. 115 shows a very practical power machine which delivers the bars perfectly straight. The machine consists of a pair of rolls, with different sizes of grooves turned in them, which pull a rod through a flaring mouthpiece and deliver it through a corresponding eye on the opposite side. The machines are made in different sizes, and will take rods from ¼-inch to ¾-inch diameter.

STEEL CASTINGS

This class of work has developed within the last few years, and, beginning with the heavier parts of marine and engine construction, is now crowding the field of drop forgings.

Steel castings are malleable, and are very much stronger than iron ones.

The principles of molding involved are similar to those in other classes of molding, but practice is varied to meet special conditions.

The art of making steel castings may be divided into three heads: (1) Preparation and melting of the metal; (2) Making and pouring the molds; (3) Heat treatment of finished castings. As the first and third heads come more properly under other departments, we shall here simply outline these processes, dealing in detail with the second heading only.

This branch of foundry work has developed to a great extent since the early nineties. The metal is similar in mixture, method of melting, and physical properties to that which is poured into ingot molds for forging purposes. The graphitic carbon is entirely burned out; the strength of the metal is therefore very much greater than that of cast iron. Combined carbon, manganese, and silicon are the elements depended upon for this strength. Sulphur and phosphorus are kept very low. A typical analysis shows:

C.	Mn.	Si.	S.	P.
0.27%	0.85%	0.35%	0.020%	0.025%

Owing to the purity of this form of iron, about 50 per cent more heat is required to melt it than is necessary in the case of pig iron—or about 3,300° F. When melted, the metal runs much more sluggish than cast iron; and, on account of the absence of graphitic carbon, it does not expand at the moment of solidifying, and therefore will not take as sharp an impression.

To insure as perfect an impression as possible, the molds are constructed with a good head of metal in risers, and they are poured under pressure. The shrinkage is double that of iron; the risers are made very large, and are placed directly on the casting to insure feeding well. Great care must be exercised that neither mold faces nor cores bind during cooling, as such binding might cause a flaw.

When two surfaces meet at right angles, the corner will remain hot longest, and the sides will shrink away, tending to cause a fracture at *a*, Fig. 116. To overcome this, thin webs are cut by the molder about every 4 inches or 6 inches—shown at *b*. These cool first, and hold the adjacent sides in position, preventing them from pulling away from each other. The internal strain due to this cooling is relieved by the annealing. After the casting is annealed, the webs are cut away.

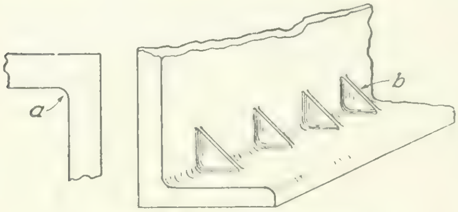


Fig. 116. Shrinkage Webbs

STEEL FACING MIXTURES

To withstand the high heat, pure silica sand is used as the basis of the facing mixtures for steel molds. Pure quartz or silica rock is quarried, and reduced to a sand form through a series of rock crushers.

At the foundry the necessary bond is given by the addition of fire clay and molasses water. These are thoroughly mixed with the sand in a facing mill and mixer (Figs. 109 and 110). A typical mixture is as follows:

1 barrow Silica Sand;
3 pails powdered Fire Clay;
Temper with molasses water.

Where quartz sand is very expensive, the mixtures made as follows will reduce the cost. The old crucibles and fire brick should be crushed separately in the mill before mixing.

INGREDIENTS	FOR CASTINGS UP TO 2 INS. THICK		FOR CASTINGS OVER 2 INS. THICK	
	I	II	III	IV
Old facing sand	8 parts	12 parts	1 part	
Old crucibles	2 "		10 parts	
Fire Brick	2 "		5 "	
Fire clay	2 "	1 part	3 "	1 part
Coke	1 part		1 part	
Silica sand		5 parts		5 parts
Graphite		2 "		

Temper with molasses water.

For *facing wash*, these mixtures are ground very fine, and thinned with molasses water.

Core sand for steel work is practically the same mixture as the mold facing. For thin metal a somewhat less refractory natural sand may be added to reduce cost of mixture.

For *small round or flat cores*, $\frac{1}{20}$ part rosin, with silica sand, tempered with molasses water, makes a good core. It should, however, be thoroughly burnt.

For *core wash* mixture, use 3 parts Silica flour; 1 part Ceylon graphite; molasses water.

STEEL FLASKS

Flasks for steel work are built up of cast iron (see Fig. 4). Full-length crossbars are bolted in the cope, 6 inches to 8 inches on centers, depending on size of flask. Short crossbars are fastened between these as needed, say 12 inches to 16 inches on centers (see Fig. 117).

Oblong bolt holes 4 inches on centers are cast in the sides of the flask and in all crossbars. Slots to correspond are cast in flanges of bars, so that they may be readily removed or shifted when fitting cope to pattern.

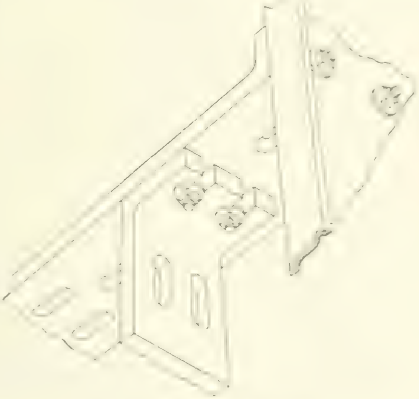


Fig. 117. Short Crossbar.

The holes for pins should be drilled to template in all flasks of the same size, so that copes and drags may be interchanged. Flask pins are slipped through holes temporarily when flask is being closed or opened. On large work the cope is bolted to drag while being rammed.

The bottom plate is of cast iron, and is clamped to flange of drag with short clamps and steel wedges.

Flasks of from 18 inches to 48 inches in length have two handles bolted on ends to lift them with. Larger flasks have trunnions, rockers, or U-shaped handles cast on the sides.

For details of cast-iron flask, see Fig. 4.

Fig. 118 shows type of convenient small flask built up of channel and angle iron, size 14 by 20 to 24 by 48 inches. The same tools are used for packing and finishing mold as described in connection with iron molding.

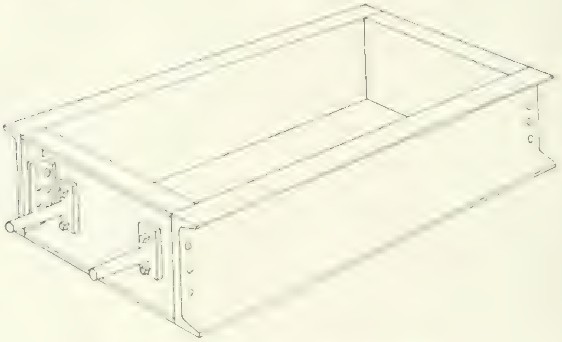


Fig. 118. Small Flask for Steel Molds

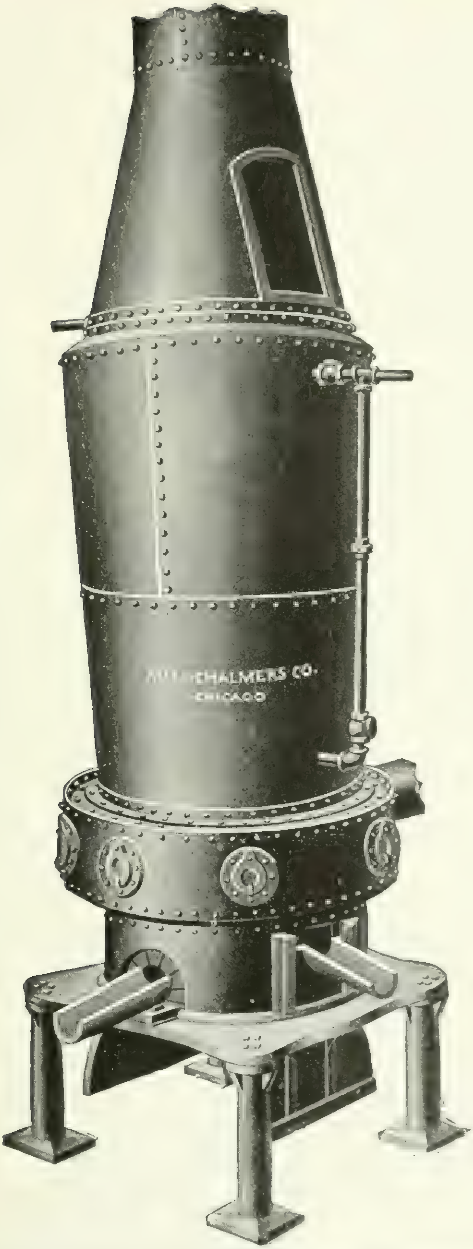
PACKING THE MOLD

In packing the mold, place the pattern on board and cover with $1\frac{1}{2}$ to 3-inch of facing, depending on size of job. Tuck well with fingers. The facing is used as prepared by the mixer, not sifted. Set drag on board, shovel in heap sand, and ram mold somewhat harder than for iron. "Strike off" and seat bottom plate, fastening it firmly to flange of drag with clamps or bolts. Roll the mold over, and remove mold board

Press with the fingers all over the joint surface, especially around the pattern, to make sure of firm packing.

If soft places are found, they should be tucked in with facing sand. When needed repairs are made, slick the joint all over. Use burnt core sand for making the parting. Try on cope and adjust bars to fit pattern. Clay wash the cope before packing. Put on necessary facing over joint and pattern. Set the gate on joint, but place risers directly on pattern. Set necessary gaggers, shovel in heap sand, and ram the cope Vent well, lift cope, moisten edges, and draw pattern.

In finishing the mold, nails are used freely (about $1\frac{1}{2}$ to 2 inches apart), driven in with heads flush with surface of sand. This is to prevent the cutting of the surface by the rush of hot metal when mold is poured.



STEEL WATER-JACKETED BLAST FURNACE FOR COPPER ORES
Allis-Chalmers Co.

It is at this stage that the thin webs previously mentioned, are cut into the corner fillets where needed. The whole surface of the mold must be smoothly slicked over with trowel and convenient slicks.

When this is done, paint on the facing wash with a very flexible long-bristled brush. Fig. 119 shows section of mold for a shrouded pinion, and illustrates points above mentioned. The runner is lead in at the bottom by use of a cover core, as described in dry-sand molding.

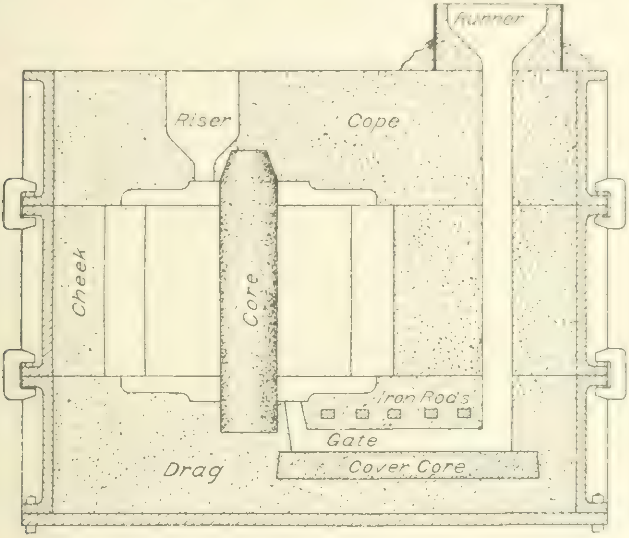


Fig. 119. Section Through Steel Mold.

Molds for steel should be more than dried; they should be thoroughly baked, to drive off every particle of moisture. This prevents the steel boiling in the mold and causing imperfections in the casting.

Where but little machine work is to be done on small work up to 1½ inches thick, the molds may be made up in wooden flasks and poured green. For this class of work, only pure quartz sand and fire clay are used, tempered with molasses water. These may be made up and poured on the same day.

STEEL CORES

Where cores must be made in halves, one set of half-cores may be made and baked. The other half is then made and rolled over directly on the baked half. Fire clay wash is used to cement the joint. This method allows the joint between halves of core to be nicely slicked down.

Cores for steel molds are made up in boxes similar to those used in the iron foundry. Although using special sands, the cores are strengthened with iron rods, vented with cinders, and provided with convenient hangers for lifting, as described in previous paragraphs.

Steel cores must be more collapsible than those for iron, on account of the excessive shrinkage of the metal. This is provided for in the mixture of the sand used, and by thoroughly backing the core to reduce the effect of the binding materials to a minimum.

MELTING

The melting of steel is a science by itself, and cannot be dealt with adequately in a paper of this character. Only a very brief description of the process will be given.

The main feature is the difference in application of heat. Metal is melted in what is termed the *Open Hearth* furnace, a sectional plan of which is shown in Fig. 120. The charge of *scrap steel* and pig iron is placed on the central hearth. Heat is obtained by producer gas supplied with air-blast. Both gas and air are heated in one set of regenerators before entering the combustion chamber The flame plays on top of the charge, and the waste gases pass off through

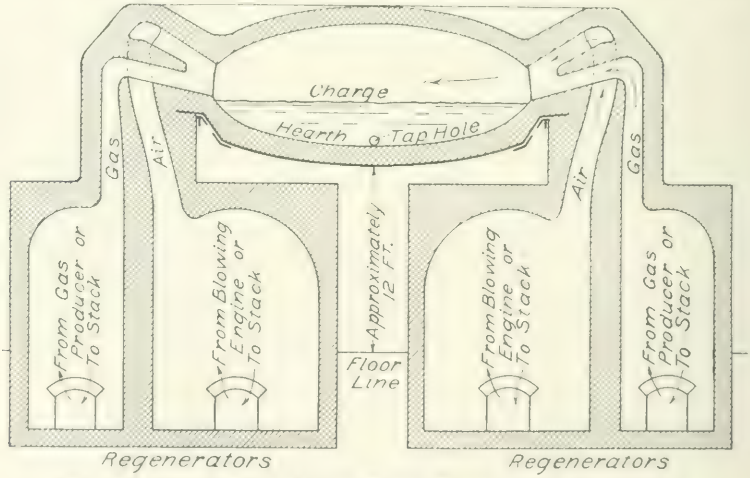

Charge
Hearth
Tap Hole
Gas
Air
Air
Gas
From Gas Producer or To Stack
From Blowing Engine or To Stack
Approximately 12 FT.
Floor Line
From Blowing Engine or To Stack
From Gas Producer or To Stack
Regenerators
Regenerators

Fig. 120. Section Through Open Hearth Furnace with Regenerators.

the other regenerator section of the furnace, heating up its brickwork. The direction of the gases is changed about every twenty minutes. The regenerator is practically a tunnel about 15 feet long, filled with brickwork built up as shown in Fig. 121. About 4 heats a day are run from the furnaces.

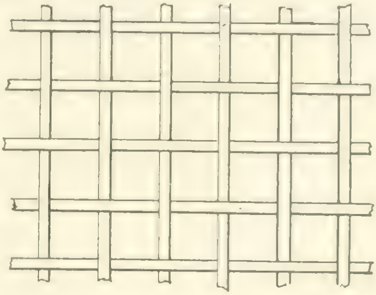


Fig. 121. How Brick is Set in Regenerator.

Samples of the bath are analyzed at intervals during the heat. Guided by these analyses the proper proportions of ores, fluxes, and pig are added to the bath to give it the right composition, a typical analysis of which has been given.

DRAWING THE HEAT

When the bath is in proper condition, the entire charge, be it 5 tons or 40 tons, is drawn off into a ladle previously heated by a special gas-burner. This ladle is lifted by the crane and carried to the pouring floor.

In order to secure the soundest metal free from pent gases or slag, all steel for casting purposes is tapped from the bottom of the ladle. The stopper is carried by a stiff round bar encased in fire-clay tubing. This passes through the liquid metal (see Fig. 122), and may be raised or lowered by an arm attached to a rack-and-pinion mechanism bolted to the outer shell of the ladle and operated by means of a large hand wheel. The ladle is swung into position with tap-hole directly over pouring head. Four men hold the ladle steady with long iron rods. The metal thus enters the mold under the head of pressure of all the steel above it in the ladle.

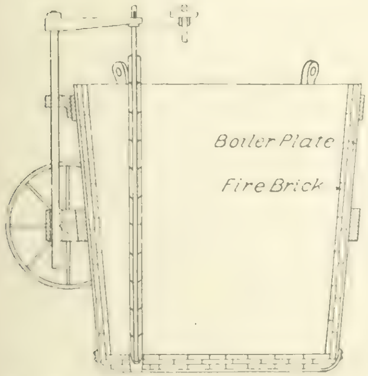


Fig. 122. Section Through Steel Ladle.

When all steel is drawn from ladle, the latter is swung on its side near furnaces, the stopper is removed, and all slag possible is racked out. The ladles must be repaired after each heat, often to the extent of replacing one-half of the thin fire-brick lining.

The casing of the stopper will last for but one heat, as the rod is sure to get bent out of shape. The rods are repaired by a blacksmith before recasing them.

SETTING UP STEEL MOLDS

This is usually done by a different set of men from those employed to make the molds.

For convenience in pouring, runner boxes (Fig. 123) are rammed up in small, round, sheet-metal boxes, using a wooden pattern to form the hole. These are baked in the oven.

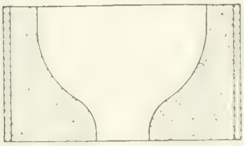


Fig. 123. Runner Box for Steel Mold.

When the molds are properly dried, they should be removed from the oven, placed on the pouring floor, and have the dust blown out with compressed air.

Now set the cores, close the mold, and clamp along joint flange. Set runner box over runner, and tuck heap sand around to prevent leakage.

This box serves simply as a funnel-shaped mouth to the runner. In pouring, the mold is filled only to the level of top of risers. The metal drains from the runner box, thus allowing it to be used more than once.

CLEANING STEEL CASTINGS

Steel castings do not run as smooth as cast-iron ones, but they have this advantage: If they show only slight surface defects, the metal may be peened over with a hammer to improve appearance.

The intense heat makes the metal burn into the sand greatly so that cleaning is much more difficult. The sand often must be almost cut from the castings by means of long cold chisels, struck with sledges. Pneumatic hammers are used to a large extent in cleaning and in removing fins and slight projections. Where shrinkage webs will show, they must be cut out. Steel will not break off as does cast iron. The heavy gates and risers must be removed by metal saws (see Fig. 124) or by drilling a number of 1-inch holes side by side through the base of the riser and then breaking it off. The castings are generally annealed before the risers are cut off.

ANNEALING

In all steel castings of any size, cooling strains will develop on account of the shrinkage. These should be relieved by annealing. In suitable trench-like ovens, the steel is heated to a dull redness. This allows the grain to assume normal conditions. The heating is usually done with a wood fire. Overheating renders the grain coarse, and weakens the casting. Proper heat treatment materially increases strength and toughness, as indicated by the following figures:

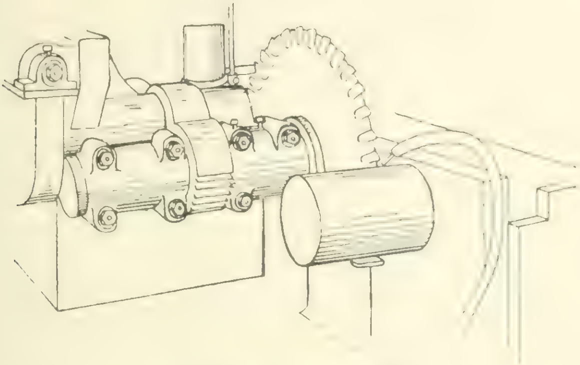


Fig. 124. Cutting off Riser.

	Tensile Strength	Elongation	Reduction of Area
Raw	80,360	13.31%	16.2%
Annealed	81,767	27.6 %	40.1%
Improperly annealed	79,421	14.3 %	17.8%

This shows that the work which is properly annealed is not only actually stronger, but is tougher and will stand more hard usage.

BRASS WORK

Cast iron and steel, which we have previously considered, are two forms of the same metal—iron. The difference in their physical characteristics is due solely to a variation in the proportions of certain elements or metaloids combined with the iron.

The metals to be dealt with in this section are termed *Alloys*—that is, mixtures of two or more separate metals.

The common alloys in use in the foundry for casting various machine parts are made from combinations of Copper, Tin, and Zinc, and are called *Brass* or *Bronze*.

Although the term Brass is held by some authorities to cover any of these combinations, the general classification accepts *Brass* as an alloy of *Copper* and *Zinc*, and *Bronze* as an alloy of *Copper* and *Tin*. In some sections the latter is spoken of as *Composition*.

Bronze has been used by man in all ages. Centuries before the Christian Era the Egyptians employed it for making coin, armor, and weapons, as well as household utensils, and statuettes of their gods. Analyses of many of these ancient relics show the composition to be almost identical with the bronzes of the present day. Brass also was in use before the time of Christ, but unquestionably bronze was of earlier origin.

A short discussion of the separate metals will help in understanding the properties of their alloys.

Copper has a red color; it is hard, ductile and very tough. It melts at about 2000° F., but it is difficult to make castings of the pure metal. Copper does not rust as does iron, and is one of the best conductors of heat and electricity. For this reason it is largely used in sheet form as a sheathing metal, and in the form of wire or rods, for electrical transmission. *Casting Copper* is put on the market in ingots of special form weighing from 18 to 25 pounds each.

Tin is a white lustrous metal, very malleable, but lacking tenacity. It may be reduced extremely thin by rolling, as is shown by tin foil. It melts at 450° F. When a bar of tin is bent it will give a crackling sound known as the "cry", which at once distinguishes it from other metals such as solder, lead, etc., which have similar external appearance. It is put on the market in pigs weighing about 30 pounds and also in bars of about 1 pound each. Its cost is approximately fifty per cent more than copper and five times as much as zinc. Tin may be cast unalloyed, and is sometimes used to run pattern letters or small duplicate patterns cast in zinc chill molds. The addition of one third to one half by weight of lead gives a cheaper metal, however, and one that will run equally well.

Tin mixed with copper gives greater fluidity, lower melting point, and greater strength, changing the color from red to bright yellow. Serviceable alloys may contain as high as 20 per cent tin. This gives a metal of golden yellow color, very hard, tough, and difficult to work.

With larger percentages of tin the color shades to gray, the metal is hard, brittle, and has little strength, and has no value for engineering purposes.

Zinc has a bluish white color; it is hard, but weak and brittle. The fracture shows very large crystals of characteristic shape. It melts at about 700° F., and shrinks but little in cooling. For this reason it may be used to cast directly for small metal patterns to form chills from which soft metal castings may be made for duplicating these patterns. If exposed to the air at high temperatures, zinc will "volatilize," that is, turn to a gas and burn. It burns with a bluish flame, and throws off clouds of dense white smoke. For this reason great care must be used to keep the air away from it as much as possible when being melted or mixed in an alloy, for aside from the loss of metal, an oxide is formed in the mixture which impairs the quality of the alloy.

Zinc is known in commerce under two names. When rolled into sheets it is called *Zinc*; when in ingot form for casting, it is called *Spelter*. These ingots are flat, approximately 8 x 17 x 1 inch thick, and weigh about 30 pounds. In this form they may be easily broken in small pieces for convenience in charging.

Zinc may be added to Copper in a very wide range of proportions, the alloy increasing in hardness and losing ductility with the increase in the proportion of zinc. The color changes from the red of the copper to a full yellow when one third zinc is used. Further additions of zinc change the color to red, yellow, violet, and gray. The alloys are serviceable up to 40 or 50 percent of zinc.

When Zinc is mixed with melted metal, considerable reaction or boiling takes place. This tends to make a more thorough mixture and to drive impurities to the surface. For this reason a small proportion, 2 to 3 per cent of zinc, is often stirred into bronze mixtures after the pot is drawn.

Lead has a bluish white color, and considerable lustre when freshly cut. It is malleable, soft and tough, but very weak. It melts at about 600° F.

Lead is not used by itself as an alloy with copper. A very small proportion may be added to the standard mixture for brass or bronze. It will cause them to run more fluid in pouring, and be softer for machining. For this reason lead is added to bearing mixtures to advantage. But it tends to deaden the color and reduce the conductivity of the metal for electrical purposes.

Proportion of Mixtures. The figures in the following table are given in percentages on one side for convenience in comparison and for figuring large heats. The beginner, however, will generally melt but one or two pigs of copper at one time. These he will weigh first and then figure the other portions of his mixture from this weight. In this case a formula given in pounds and ounces is much simpler.

Percentages				USE	Lbs.	Ozs.		
Copper	Tin	Zinc	Lead		Copper	Tin	Zinc	Lead
83.	12.	2.5	2.5	Gun metal for bearings. A very tough hard mixture.	1	2½	½	½
85	7.	5	3.	Steam or Valve metal. Cuts freely, very tough, resists corrosion.	1	1¼	¾	½
90	5.	5.		Composition. For general use on small machine parts.	1	1	½	
90	6.	3.	1.	Bronze for Art work. Rich color, runs fluid at comparatively low heat.	1	1	½	¼
66.5		33.5		Common Yellow Brass. Good for general run of machine castings.	1		8	
66.	33.		1.	Same as above. Will machine a little easier.	1		8	½
1.80	64.70	33.35	1.	Anti Friction metal. For journal boxes.	⅛	32	16	½
	66		34.	Good mixture for small patterns. Runs well, shrinks little.		2		1

From what has been said it will be understood that it is possible to vary these mixtures to meet special conditions. To harden or toughen an alloy increase the tin; to soften it reduce the tin. The same is true with zinc, but it will require larger proportionate changes in this metal to effect similar results in the alloy.

Phosphorus is not a metal, but is a very active chemical element manufactured from bone-ash. It has such an affinity for the oxygen of the air, that in its pure state it must be kept under water, because the slightest scratch would cause it to burn fiercely. It forms the principal substance used in making the heads of matches.

As a rule it is never used in the foundry in its pure state. For the production of *Phosphor Bronze* castings there are several combined forms of phosphorus on the market. The most convenient of these is known as *Phosphor Tin*. This is metallic tin carrying various fixed percentages of phosphorus of which 5 per cent is one very common proportion. Knowing the amount of phosphorus carried by the tin, the exact proportion for the entire alloy may be readily calculated.

This element should not be used in alloys containing zinc or lead. It acts as a flux, combining with any oxidized or burned impurities in the bath of metal and driving them to the top. It tends to make the tin crystalline in form, in which condition it unites more firmly with the copper. It apparently unites chemically with copper, making that metal harder. The proportion of phosphorus should not exceed .75 per cent, while .25 to .40 per cent are safer proportions.

Two typical mixtures, using 5 per cent phosphor tin, are as follows:

PHOSPHOR BRONZE MIXTURES

For a Tough Alloy	For a Hard Alloy		For a Tough Alloy	For a Hard Alloy
90. %	87.50 %	Copper	9 lbs.	8¾ lbs.
9.75	12.25	Tin	½ lb.	¾ lb.
.25	.25	Phosphorus		
		Phosphor Tin	½ lb.	½ lb.
100.	100.	Totals	10 lbs.	10 lbs.

MATERIALS

Natural molding sands are used for brass-work. They are usually finer than sands used in iron-work, because brass parts are generally small and often have fine detail which must be brought out very sharp in the mold. For this reason also the sands should have more alumina or bond than iron sands.

This increase of bond is possible because the metals entering the mold are not as hot as iron, therefore do not require as much vent, but they have a greater tendency to "cut" the mold.

For the general run of work the whole heap is kept in good condition by the frequent addition of new sand, but on large work a facing mixture is used similar to the Iron Foundry.

Burnt sand, powdered charcoal and partimol are all good *parting materials*. The last two are best on small work, as they make a cleaner joint. They are not blown off of the patterns, because they make a good facing for the mold.

The brass molder uses practically the same kinds of tools, such as shovels, sieves, rammers, and molder's tools generally, as already described.

Snap Flasks may be used, but the pins, hinges and catches must be kept in careful adjustment so that the parts of the mold shall register perfectly. The same is true of the larger box flasks for floor work.

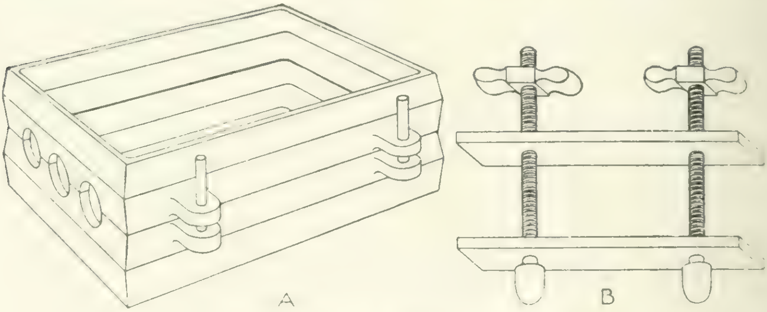


Fig. 125. (A) Flask for Brass. (B) Screw Clamp.

The most typical *brass flasks* are of cast iron with accurately fitting round steel pins. See Fig. 125 A. They have holes on the joint at one end of the flask so that the mold may be set upright when pouring.

This gives a decided additional pouring pressure with a minimum thickness of sand over the castings.

Boards without cleats support the sand in the flask and the whole is clamped before setting on end by means of some form of double screw clamp similar to the illustration, Fig. 125, B.

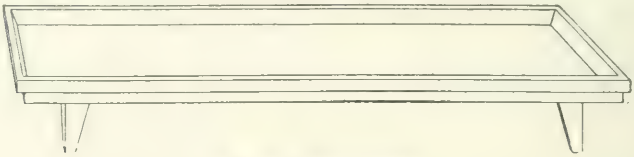


Fig. 126. Spill Trough.

Great care is taken in the brass shop to save all shot and spilled metal possible. To this end, when the molds are to be poured on end they are leaned against a cast iron *Spill trough* shown in Fig. 126. There should be a 1-inch layer of sand over the bottom of this tray. The crucible is held over it when pouring the molds, thus making it possible to conveniently catch any metal that is spilled.

For thin work the face of the molds are *skin dried* to drive off the moisture before the metal enters the mold. *Drying stoves* similar to Fig. 127, are used for this purpose. When the mold is finished the two halves are carefully sprayed with a weak molasses water, and the flask is set on end on the wide platform with the face of the mold next the stove. When sufficiently dry the mold is closed and poured at once.

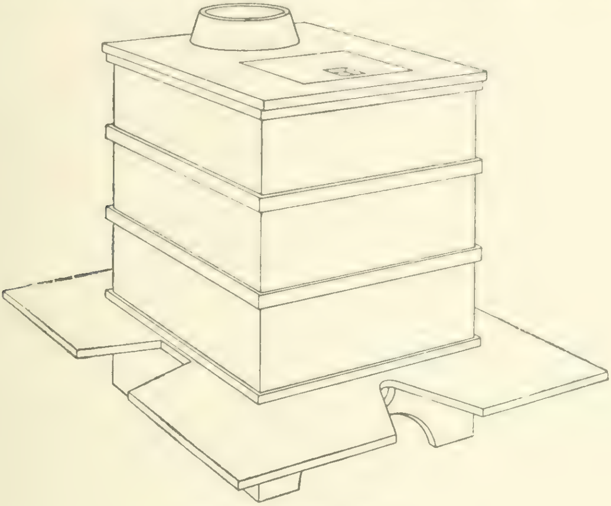


Fig. 127. Drying Stove.

PRINCIPLES OF THE WORK

Brass work deals as a rule with smaller quantities in every way than does iron work. The patterns are generally smaller and the brass molder takes particular pride in making all his joints so neat that hardly a fin will show on his castings. The matter of catching the shot metal has been mentioned. Up to the introduction of the oil-melting furnace it was customary to heat a pot of metal for each molder. These heats were comparatively small, so that he would make up possibly six or eight molds, then draw his pot and pour them; running in this way several heats in a day.

Using the furnace, several heats are run each day, but a much larger quantity of metal is melted at each heat, so that the work of several molders is poured with exactly the same metal.

A mold for brass should be rammed about the same as for iron. On name plates and thin work, after the initial facing of sifted sand has been properly tucked with the fingers, the flask is filled heaping full of sand. Then by the aid of a rope hanging down from the ceiling, the molder springs up on top and packs the mold with his feet, the weight of his body giving the right degree of firmness to the sand. Stove-plate molders often pack their flasks in the same way.

The main difference between making up molds for brass and those for iron are due to three causes: Brass melts at a lower heat; it does not run as fluid as iron; it has about double the shrinkage of iron.

For these reasons the sand may be somewhat less porous and still vent sufficiently, if risers are placed to allow for the escape of the air. On bench work the vent wire is not used.

The runners for brass should be larger than for iron, and the gates, instead of being broad and shallow, should be more semicircular in section. Pouring molds on end gives the pressure necessary to force a more sluggish metal to take a sharp impression, and the heavy runners shown in the following examples serve to feed the casting as it shrinks.

Forms of skimming gates, as explained in an early section, are used to advantage on work of a very particular nature.

EXAMPLES OF WORK

To illustrate more clearly some of the typical methods of brass work, let our first example be a thin flat plate with decoration in low relief on one side.

Place the pattern face down, a little below the center of flask. Sift on facing through a No. 16 sieve, then tuck, fill and pack as previously described. Roll over and make a joint. Now cut a half section of the main runners and risers, but do not connect them with the mold at this stage. Dust on parting material from a bag, and ram the other half of flask just hard enough to stand handling. Separate flask; spray face of mold with weak molasses water, and dust on it from a bag some finely powdered pumice stone, or any fine strong sand, and over this a little parting dust. Now replace this half over the pattern and re-ram to the required firmness and again separate and this time draw the pattern.

The impression of the runners and risers cut in the first half of the mold will show as ridges on the second half packed, and serve as guides for cutting the runners to a full round section. Connect the gates in four places, as shown in Fig. 128 A. Skin dry the mold and it will be ready to close and pour.

Dusting fine sand on the face of the mold then reprinting, as it is termed, ensures a very smooth, perfect mold face. Where the mold is not skin dried, *flour* is dusted over the face, allowed to stand for a short time, and then blown off. This makes a good facing.

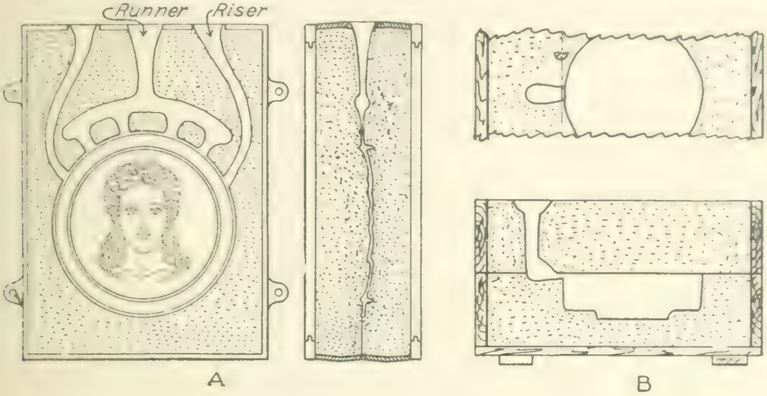


Fig. 128. (A) Mold for Thin Plate.—(B) Mold for Heavy Plate.

Cutting the heavy runner over the top of the thin plate ensures a sufficient supply of clean hot metal to the gates under pressure enough to force the metal into every detail of the mold before it has time to chill.

B, Fig. 128, shows the difference in construction of gate when a heavier piece is cast with the flask setting horizontally. The gate proper is cut in the drag, but a good feeding head is cut out of the cope side to keep the metal in the riser liquid until the casting has solidified.

For duplicating work the sand match, oil match, or follow board are used; the same as for iron work.

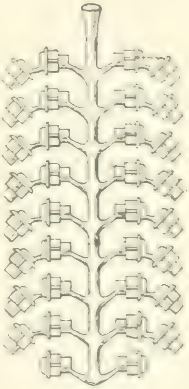


Fig. 129. Duplicate Gated Work.

Fig. 129 shows a typical set of castings run from the end and made from gated patterns set in an oil match. Steady pins are placed on the gates to facilitate a clean lift.

Cores for brass work are made up as previously described. To give a smoother surface on the small cores about one third molding sand is often mixed in with the beach sand of the stock mixture.

CLEANING

When the castings are taken from the sand they should be rapped smartly to free all loose sand, then, if machining is to be done on them, they should be plunged, while hot, into water. This softens the castings. This method is used also to *blow out* cores from small work.

A Sprue Cutter, shown in Fig. 130, is part of the equipment of a brass foundry. These machines are made to operate by foot as shown or by power. With them the castings are cut neatly and quickly from the runners.

Brass does not burn into the sand as much as iron, therefore, in many shops, the small castings are brushed clean before being cut from the gates, by means of a *circular scratch brush* mounted on a spindle similar to a polishing wheel.

A good method of cleaning brass and bronze is by *pickling*. Make a mixture of 2 parts common nitric acid and 1 part sulphuric acid, in a stone jar. Place the piece to be cleaned in a stone *dipping basket*, Fig. 131, and dip once into the acid, then wash off in clean water and dry in sawdust.

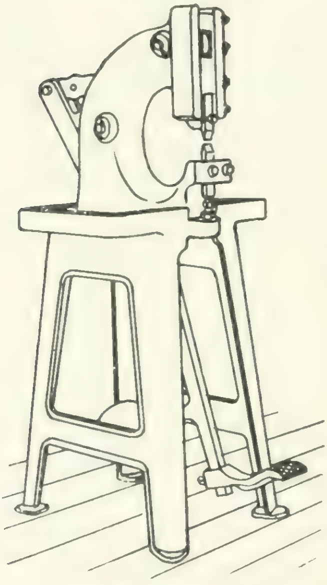


Fig. 130. Sprue Cutter.

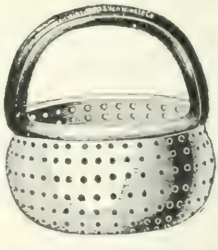


Fig. 131. Dipping Basket.

In many cases brass chips and filings will be turned back to the foundry to be remelted. The smallest portions of steel or iron in these would prevent their being used in this way, as they make extremely hard spots in the castings.

Fig. 132 shows a *magnetic separator* which effectively removes all steel and iron chips. The brass chips and sweepings from the machine shop are placed in the hopper of this machine. They are caused to be spread out on one side of a slowly revolving brass covered drum, A. Inside of this brass shell are strong magnets which hold the steel and iron chips to the surface while the brass chips drop off into a tote box. A stiff brush at the back of the cylinder removes the iron chips and they drop into a separate box.

MELTING

All alloy metals burn if exposed to the air while melting, and especially zinc and tin. To prevent this burning the brass melter endeavors to control the draft in his furnace so that all oxygen entering the gates will combine with the fuel, so that gases which may reach the metal shall contain no free oxygen.

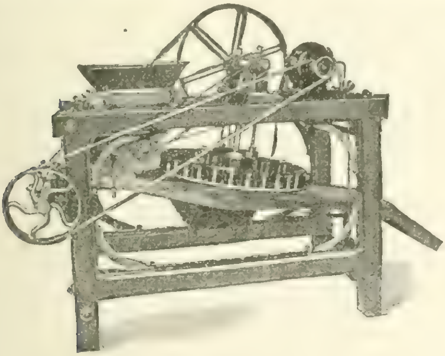


Fig. 132. Magnetic Separator.

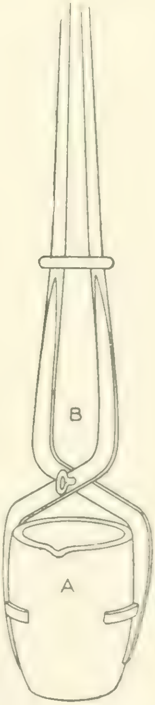


Fig. 133. (A) Crucible.
(B) Tongs

For this reason the ordinary brass furnace is a natural-draft furnace, although a forced draft is often connected below the grates to make combustion independent of atmospheric conditions.

The metal does not come in direct contact with the fuel, but is contained in fire-clay pots called crucibles, which are bedded in the fire. Hard coal or coke is used for fuel.

These *crucibles*, Fig. 133, A, are manufactured from a very refractory fire-clay mixture and are strong and tough even at a high temperature. They are lifted in and out of the furnace by the tongs shown at B, Fig. 133. For the larger sizes a crane is used for hoisting the pot.

Crucibles are made in a great variety of sizes, as they are used in many different metal industries, from that of the jeweler to that of the steel manufacturer. They are classed by number, the following table gives data regarding a few sizes.

SIZES OF CRUCIBLES

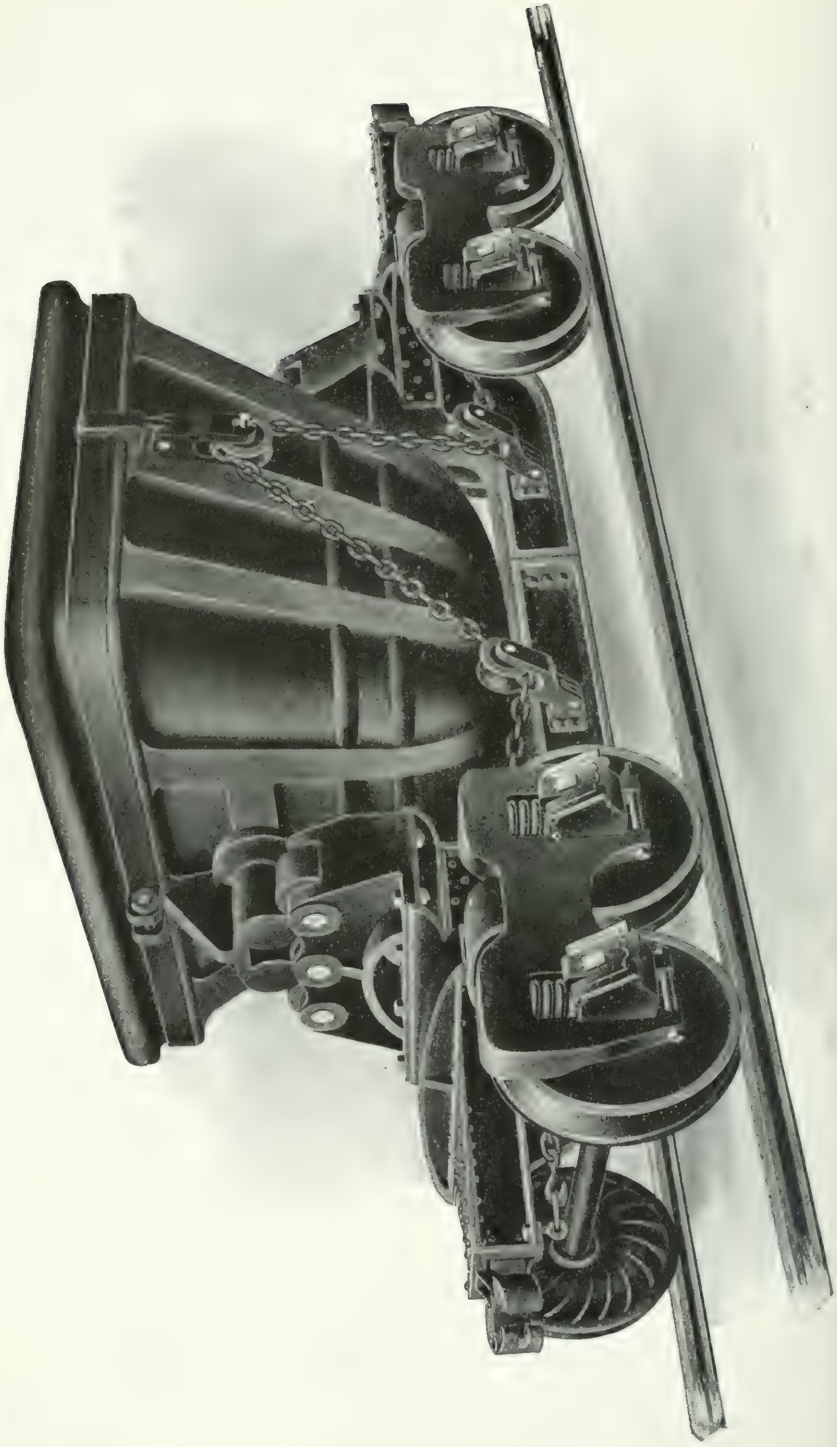
Nos.	Holding Capacity Liquid Measure			Height Outside	Diameter at Top Outside	Diameter at Bilge Outside	Diameter at Bottom Outside	Capacity in Weight of Water
	Gal.	Qt.	Pt.	Inches	Inches	Inches	Inches	Pounds
0				2	1¼	1⅝	1¼	
0000				3	2	2½	1½	
6		1		6½	5¼	5¾	3¾	2.08
12		2		8	6¾	6¾	5	4.16
30	1	1	1	11	8½	9¼	6½	11.5
60	3			14	10½	11½	8	25.
90	4			15¾	11½	12½	9	33.3
300	12	2		22	16¾	17½	12½	104.

The melting capacity of any of these sizes may be obtained by multiplying the figure given in the column "Weight of Water" by the specific gravity of metal to be used.

New crucibles should always be *annealed* before using, that is, brought very slowly to a low red heat. This drives out any moisture absorbed from the air since coming from the kiln in which they were baked. Disregard of this generally results in a cracked crucible.

Natural Draft Furnaces are usually called brass furnaces, and may be bought on the market made up in single complete units.

Fig. 134 illustrates one of a battery of several furnaces connecting with a common flue. The top is on a level with the molding floor. The sketch shows clearly the principles of construction. A cast iron bottom, plate A, with a circular opening, carries a shell of boiler plate lined with fire brick. The diameter of the inside lining should be 6 inches larger than the crucible to be used. A top plate, with a similar opening, binds the whole together. On one side, below the top, an opening, B, which may be formed by a cast iron box, connects with the flue or stack. Two heavy ribs, cast on the bottom plate, rest on a pair of rails as shown, and these rails are supported by suitable piers of



brickwork, about two feet high, so that ashes may be conveniently removed when the furnace is dumped. In the space between the bottom plate and rails, made by the ribs, the grate bars, C, are set. These bars are loose and may be pulled out when it is desired to dump the fire for the day.

Operation. In running off a heat a bed of freshly lighted fuel about 8 inches deep is made over the grate bars. The crucible, packed as full as possible with the charge, is lowered in and the space around it filled with fuel. The crucible should be kept covered, especially for brass. In melting brass, melt down the copper first, then the scrap. When this is melted, charge the zinc and stir well before lifting the pot. Allow the mixture to come to the proper heat again, then pull the pot, skim off the dross, and stir in the lead if any is called for, just before pouring.

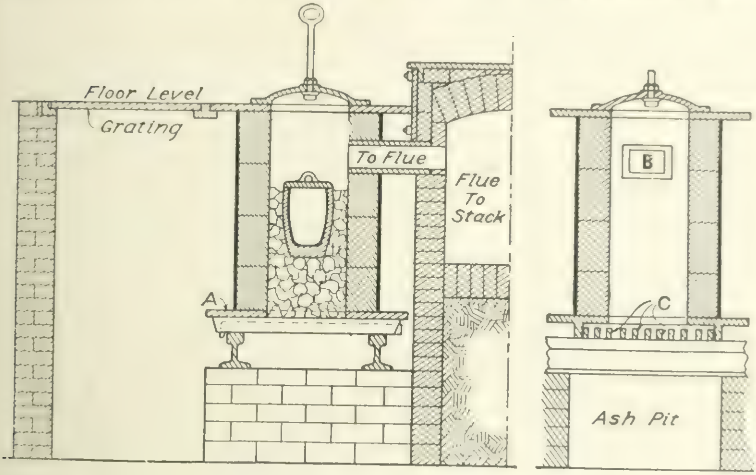


Fig. 134. Natural Draft Furnace.

In bronze the same method is pursued, but both the tin and zinc are stirred in after the pot is drawn.

In mixing in the zinc in brass, care must be taken to plunge it well under the surface of the copper with long handled pick-up tongs, and to hold the piece down with the stirring bar until it has melted.

Where a large casting requires more metal than can be melted in a single crucible, several furnaces must be used and the contents of their various crucibles assembled into one large pouring ladle just before pouring.

Gas or Oil Furnace. With the development of natural gas and crude oil burners for commercial heating, several good furnaces have been designed in which a large quantity of metal can be melted at one time.

Fig. 135 shows a furnace of this character in section. This type has tandem melting chambers with burners at the end, which may be used separately or both together. The waste gases from the bath of liquid metal are used to heat up a fresh charge in the other chamber. The metal is charged and poured from the openings at the top of the furnace. Each chamber may be revolved separately, to empty the furnace when the charge is melted. Fig. 136 shows the general arrangement of the oil feed pump, and blower for these melting furnaces.

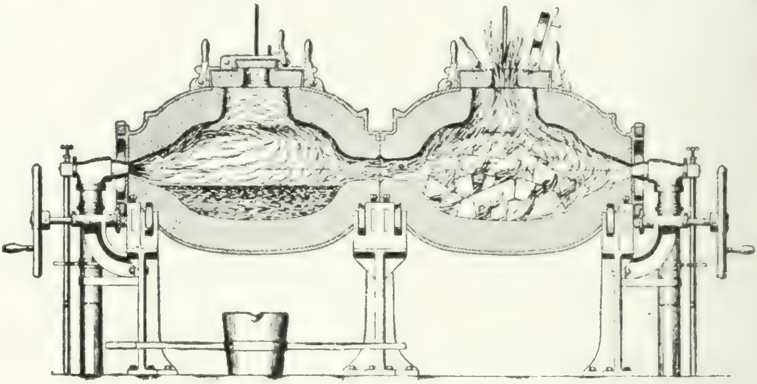


Fig. 135. Section Through Oil Furnace.

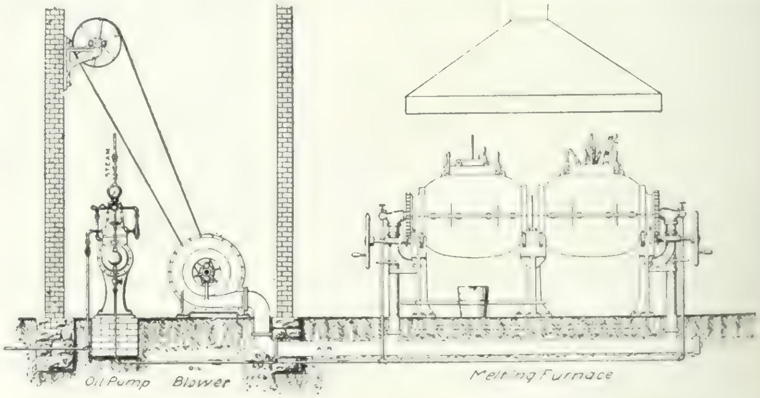


Fig. 136. Oil Furnace—General Elevation.

The flame plays directly on to the metal. The oil pressure should remain constant at about 5 pounds per square inch. But the air pressure is regulated to vary the intensity of the heat as desired.

The pouring ladle must be well heated before using. This is done with a special gas burner, or when crucibles are used, they are often heated by means of a small fire in an ordinary furnace.

Different sizes of furnaces are built to melt from 250 to 2000 pounds of metal at a heat. Twelve or fourteen heats a day can be run. The saving is approximately 50 per cent in time and is also very considerable in expense, over ordinary crucible furnaces of equal capacity.

SHOP MANAGEMENT

The success of a foundry depends upon the ability of its managers to promptly turn out castings which will meet the requirements demanded of them, at the lowest possible cost commensurate with the quality of the work. In this chapter we wish to direct the attention of students to some features in the way of equipment and management which aid in accomplishing these results.

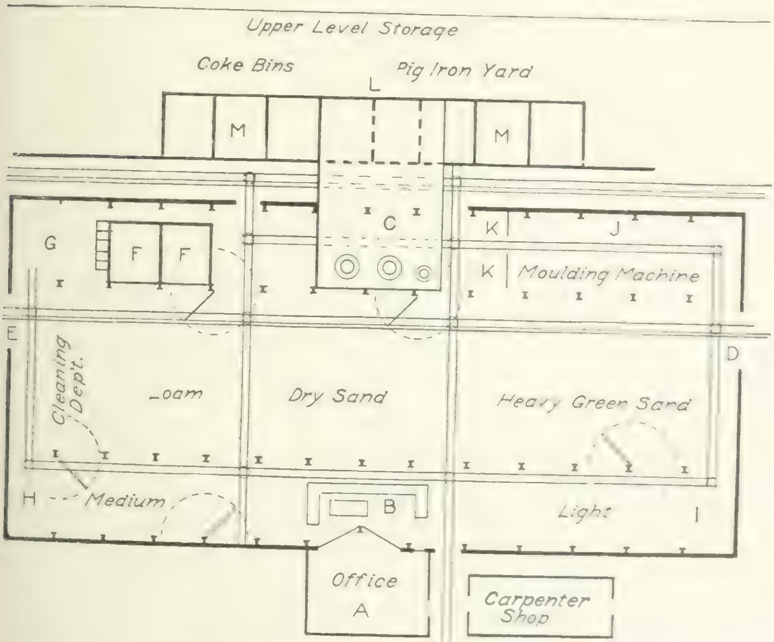


Fig. 137. Typical Plan of Foundry.

The most important processes in the foundry are melting metal, making molds, and pouring them. Much of the work necessary in preparing for these processes consists of handling heavy materials such as coke, iron, sand, etc. To reduce this handling to its lowest limits, as to distances, number of re-handlings, and methods of conveyance, are problems to be considered in the plan of the shop as a whole.

To briefly illustrate some of the points to be brought out, let us consider the plan of a shop shown in Fig. 137, and its sectional elevation shown in Fig. 138.

The building is of steel construction and the columns supporting the roof trusses serve also to carry the tracks for the overhead traveling cranes.

The outer walls should be filled in with some good weather-resisting material of which there is nothing better than brick. These walls should be of good height and have a sufficient window area to supply light well in toward the middle of the shop.

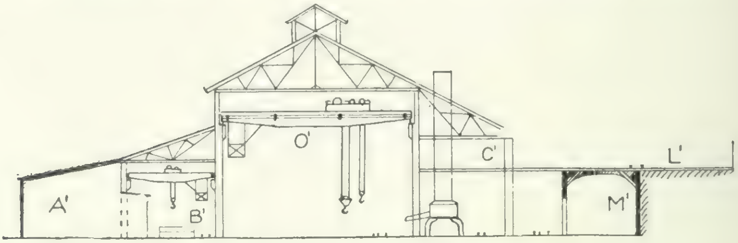


Fig. 138. Typical Elevation of Foundry.

The method of heating and ventilation best adapted for a foundry is the indirect fan system. One or more large fans situated generally toward the ends of the shop, draw fresh air in through a compact system of steam coils, and by means of overhead piping deliver it to all portions of the shop. The impure gases are carried off through ventilators in the clear story at the top of the roof.

The floor of the foundry should consist of molding sand, the depth of the sand floor varying with the class of work to be done. If the natural soil of the grounds is open and porous, a thickness of 3 or 4 inches of clay well rolled down should be put in underneath the sand floor. This will help greatly in keeping the molding floor in good condition, as it prevents the moisture draining out of the sand.

The foundry office should be located at such a point that the foreman can command a view of the whole shop. It should be convenient to the different departments and at the same time be protected as far as possible from dust. The office room, shown in Fig. 137 at A, is built on the outside of the main building, but has a large bay window which projects a few feet into the shop from which all corners of the foundry can be seen.

A space B having suitable low tables and shelving, is reserved near the office for the temporary storing of patterns in daily use. This brings them directly under the attention of the foreman and his assistants who can readily check the patterns as they come in and quickly find those requiring prompt attention.

At C is shown the cupolas, directly opposite the foreman's office, and so situated that all of the molding floors may be served as quickly as possible without interfering one with the other.

In large foundries there are two or more cupolas, to admit of different mixtures being melted simultaneously. Often a comparatively small cupola is installed near the floor for light work for the service of that floor alone.

The blowers should be placed near the cupolas avoiding long connecting wind pipes. The application of electric motors removes the necessity of concentrating the power at one point in the shop.

The main bay of the foundry is devoted to the heaviest work and is served by at least two overhead cranes.

The heavy green sand castings are made at one end so that the flasks for this work may be stored in yards near by and be brought in through the door D. These molds are made up furthest from the cleaning shed because only the castings themselves need be transferred there.

The flasks and rigging for the dry sand and loam molds should be brought in through the opposite door, E. The loam work as a rule is the most bulky to handle and should be nearest the cleaning sheds so that it need not be carried across the other floors. Both dry sand and loam floors are convenient to the large ovens, F.

The core shop is situated in the side bay at G, to make it convenient to swing the large cores on to the buggies to be run into the large ovens. A jib crane near the corner of these ovens makes the men working on such cores independent of the traveling crane. The ovens for small cores are built along the side of the large ovens and utilize the same stoke hole, ash-pit and stack.

Distributed through the side bays also are the medium work floor H the light work floor I and the molding machine floor J. This ensures a supply of good light necessary to the smaller details of this class of work.

The molding machines are placed on that side of the shop near the sand storage sheds, to allow for handling the sand by means of belt conveyors, with hoppers above the machines, an illustration of which is shown in Fig. 139.

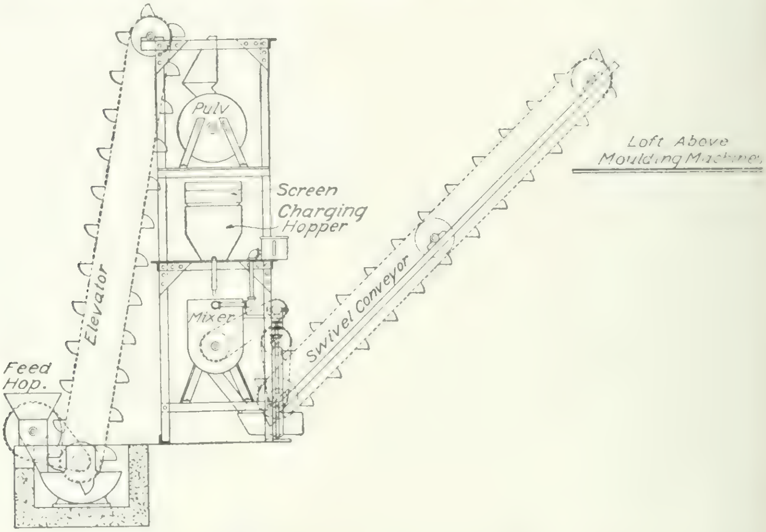


Fig. 139. Automatic Sand Mixer.

The sand-mixing space is in the side bay near the cupolas at K, and is furnished with power from independent motors or from a jack shaft leading from the blower room. This position affords direct access to the sand bins. The raw material after being mixed and tempered is delivered by barrow or sand car direct to the various floors. The mixers might be installed in one of the storage vaults across the roadway.

The quickest means of unloading either wagon or carload lots of material is by dumping, where the material can be so handled. One of two things is necessary to accomplish this: either the storage bins must be placed in a basement underneath the roadbed, or the roadway must be run up an incline over the top of the bins. The former method is more frequently met with in the crowded condition of the large cities, but the latter is preferable because less time is consumed in running material up an incline in large quantities than will be required to hoist small quantities more frequently from a basement.

At L and L′, Figs. 137-138, is shown the storage yards for pig iron and coke; these are on a level with the charging platform of the cupola C C′, and can be loaded on cars and pushed directly to the charging door. In some modern shops these push cars are built so that their load may be dumped as a whole into the cupola.

The storage for core oven fuel, sands and clay, is shown at M M, in bins built underneath the tracks and on a level with the foundry floor. These bins should be arranged to open on top with a shute under the track and a trap at the side so that coal or sand may either be dumped or shoveled directly into them.

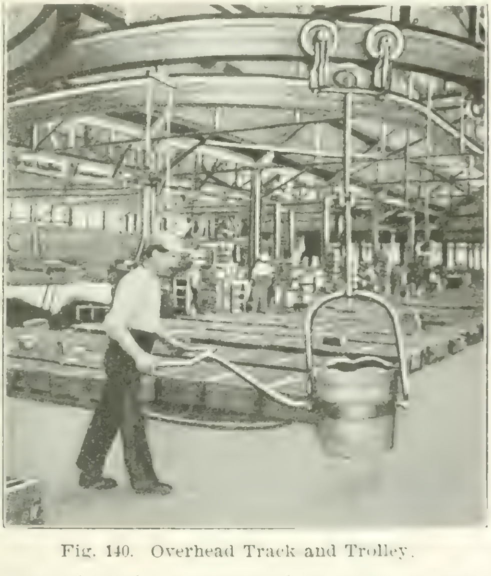


Fig. 140. Overhead Track and Trolley.

In the largest shops a standard gauge track should run directly through the main foundry, also similar tracks through the roadway next the cupola bay, for convenience in removing the dump. The track over the storage bins has been mentioned.

Two methods of transferring material between departments within the shop, aside from the cranes, are the overhead trolley system, Fig.

140, and the narrow gauge industrial railway. The former is of advantage in manufacturing plants where the loads to be transferred are nearly uniform in weight and frequency of handling. This system leaves gangways smooth and free from obstructions. For general work, however, the industrial railways are more frequently installed. These serve all floors to deliver flasks, sand, or iron, and to remove castings.

Of the many styles of overhead traveling cranes that are on the market those using electricity as the motive power are undoubtedly the most serviceable. The cranes in the main foundry indicated at O′, Fig. 138, should have two hoisting drums on the carriage; one for such light work as handling flasks, rigging and patterns, the other for the heavy work on the large ladles and castings.

Small jib cranes furnished with a 2- to 4-ton air or electric hoist placed on the side of a man's floor make it possible for the molder and helper to handle work of considerable size by themselves, and prevent loss of time waiting on the overhead crane.

The method of distributing the melted metal varies with the class of work made. In shops doing general jobbing work, the ladles for pouring the largest work are carried from the cupola direct by the overhead cranes.

For serving the floors in the bays one of the systems mentioned above is generally used. The metal is conveyed to the floor in a large ladle and from this smaller ones are filled and carried by hand or by a small crane to the molds.

The cleaning department should be situated at one end of the shop near E, Fig. 137, or in a shed extension to the foundry proper. It requires space to pile the castings as they are brought from the floors with sufficient room for the men to begin work on these piles. As a rule the smaller castings are first collected and put through the tumbling barrels, then the medium work is cleaned by hand or sand blast; this leaves room for work around the largest pieces. As soon as castings are cleaned they are weighed and shipped to the customer, store house, or to the department which does the next operation upon them.

DIVISION OF LABOR

The division of labor in a foundry is briefly as follows:

The superintendent is responsible for the operation of the foundry as a whole. He hires the men and oversees the purchase of material and supplies, having under him clerks who keep track of the details of this work. Some of the things to which he gives personal attention are:

In consultation with his foreman he gives personal attention to the receipt of the most important patterns; decides how they shall be molded; on what floor and what mixture shall be used to pour them. He devises ways and means of increasing the productiveness of his shop.

The foreman or his assistants must be in the shop a sufficient time before work begins for the day to see that each molder has work laid out for him, and must keep the men supplied with work through the day. He estimates the amount of the charge for the day and directs the melter as to mixtures.

It is the duty of the foreman and his assistants to give directions to the apprentice boys and to see that these directions are carried out to the best of the boys' ability.

The molders should give their entire time to making up molds. On floor work they are usually given a helper who totes flasks, cores, chaplets, etc., and does the heavier work when handling the sand. When the molds are poured and his flasks stripped off the molder is through for the day.

Most modern shops employ a night gang of laborers to put the shop in proper shape for the molders to start their special work immediately when the whistle blows in the morning. These men remove the castings from the sand and transfer them to the cleaning shed. They pick out all bars and gaggers used in the molds and stow them in place. They temper and cut the sand and dig any pits necessary for bedding in work.

CHECKING RESULTS

The methods of mixing iron by analysis have been dealt with in an earlier chapter, but these mixtures must be checked by physical tests on the resulting castings.

Two systems are now in more or less general use throughout the United States.

Mr. W. J. Keep, of Detroit, Michigan, who has had long experience in this subject, has invented a very complete system of regulating mixtures which he terms "Mechanical Analysis." Fig. 141 A shows a follow board arranged with patterns and yokes. The test bars are ½ inch square and 12 inches long. They are cast in green sand with their ends chilled against the faces of the cast iron yokes, shown in the cut. Three molds should be cast each heat, and the test bars allowed to cool in the molds.

Mechanical Analysis is based on the fact that silicon is the most important variable chemical element in cast iron, and that shrinkage in castings is directly proportionate to the silicon in the mixture.

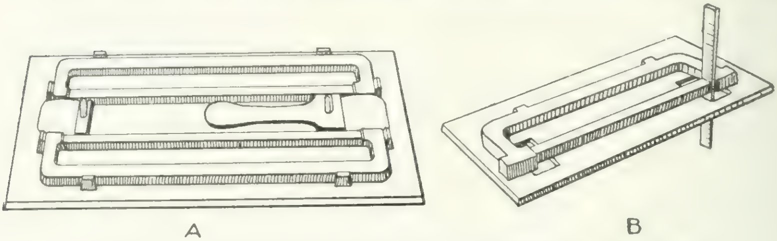


Fig. 141. (A) Keep's Test Bar Pattern.—(B) Measuring Shrinkage.

The first test is to replace each bar in the same yoke in which it was cast and by means of a specially graduated taper scale ascertain accurately the amount of shrinkage. See Fig. 141, B.

The shrinkage of the bars when the castings prove satisfactory should be considered the standard for that class of work for that shop. If at any time the shrinkage is greater than the standard, increase the silicon by using more soft pig; if it is less, decrease silicon by using more scrap or cheaper iron.

The depth of chill on the castings is measured after chipping off a piece from the end of the bar.

The third test is to obtain the transverse strength of each bar. This is done on a special testing machine which gives a graphical record of the deflection and ultimate breaking load. These dead loads will vary with different mixtures approximately from 340 to 500 pounds.

Quoting from Mr. Keep's circular:

> "With high shrinkage and high strength of a ½-inch square test bar, heavy castings will be strong but small castings may be brittle.
>
> "With low shrinkage and high strength large castings will be weak and small castings will be strong.
>
> "With uniform shrinkage an increase in the strength of a ½-inch square test bar will increase the strength of all castings proportionately."

The other form of tests was devised by a committee of the American Foundrymen's Association, and is recommended in the Proposed Standard Specifications for Gray Iron Castings by the American Society for Testing Materials. A partial summary of these specifications is as follows:

> "Unless furnace iron is specified, all gray castings are understood to be made by the cupola process.
>
> "Light castings are those having any section less than ½ inch.
>
> "Heavy castings have no section less than 2 inches.
>
> "Medium castings are those not included in the above."

The test bar is 1¼ inches in diameter and 15 inches long, and is known as the "Arbitration Bar." The tensile test is not recommended but if called for a special threaded test piece is turned down from the "Arbitration Bar," and has a test section .8 inch in diameter and 1 inch between shoulders.

The transverse test is made with supports 12 inches apart.

Fig. 142 shows a sketch of the patterns for these bars. Two bars are rammed in a flask and poured on end. The small prints on the two bar patterns project into the cope and are connected by one pouring basin. A special green sand mixture is specified for making these molds; the molds are to be baked before pouring, and the bars allowed to remain in the sand until cold.

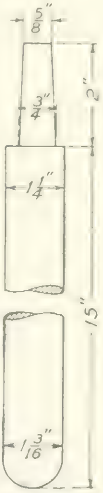


Fig. 142
Pattern for Arbitration Bar.

The following table shows the specified requirements:

TESTS ON "ARBITRATION BAR"

Grade of Castings	Chemical Properties	Physical Properties	
	Sulphur Content Not Over	Transverse Test* Minimum Breaking Strength	Tensile Strength Not Less Than
Light castings	0.08 per cent	2500 lbs.	18,000 lbs. per sq. in.
Medium castings	0.10 per cent	2900 lbs.	21,000 lbs. per sq. in.
Heavy castings	0.12 per cent	3300 lbs.	24,000 lbs. per sq in

*In no case shall the deflection be under .10 of an inch.

RULES AND TABLES

MENSURATION

Circumference of a circle = diameter × 3.1416
Area of a square or rectangle = base side × height
Area of a triangle = base × perpendicular height
Area of a circle = diameter squared × .7854
Convex surface of a cylinder = circumference × height
Convex surface of a sphere = circumference × diameter
Contents of a rectangular solid = area of base × height
Contents of a cylinder = area of base circle × height
Contents of a sphere = cube of diameter × .5623
One side of square having same area as given circle = diameter × .8862 or circumference × .2821

AREAS OF CIRCLES AND THEIR CIRCUMFERENCES

Diameter	Area	Circumference	Diameter	Area	Circumference	Diameter	Area	Circumference	Diameter	Area	Circumference
⅛	0.0123	.3926	10	78.54	31.41	30	706.86	94.24	65	3318.3	204.2
¼	0.0491	.7854	½	86.59	32.98	31	754.76	97.38	66	3421.2	207.3
⅜	0.1104	1.178	11	95.03	34.55	32	804.24	100.5	67	3525.6	210.4
½	0.1963	1.570	½	103.86	36.12	33	855.30	103.6	68	3631.6	213.6
⅝	0.3067	1.963	12	113.09	37.69	34	907.92	106.8	69	3739.2	216.7
¾	0.4417	2.356	½	122.71	39.27	35	962.11	109.9	70	3848.4	219.9
⅞	0.6013	2.748	13	132.73	40.85	36	1017.8	113.0	71	3959.2	223.0
1	0.7854	3.141	½	143.13	42.41	37	1075.2	116.2	72	4071.5	226.1
⅛	0.9940	3.534	14	153.93	43.98	38	1134.1	119.3	73	4185.3	229.3
¼	1.227	3.927	½	165.13	45.55	39	1194.5	122.5	74	4300.8	232.4
⅜	1.484	4.319	15	176.71	47.12	40	1256.6	125.6	75	4417.8	235.6
½	1.767	4.713	½	188.69	48.69	41	1320.2	128.8	76	4536.4	238.7
⅝	2.078	5.105	16	201.06	50.26	42	1385.4	131.9	77	4656.0	241.9
¾	2.405	5.497	½	213.82	51.83	43	1452.2	135.0	78	4778.3	245.0
⅞	2.761	5.890	17	226.98	53.40	44	1520.5	138.2	79	4901.6	248.1
2	3.141	6.283	½	240.52	54.97	45	1590.4	141.3	80	5026.5	251.3
¼	3.976	7.068	18	254.46	56.54	46	1661.9	144.5	81	5153.0	254.4
½	4.908	7.854	½	268.80	58.11	47	1734.9	147.6	82	5281.0	257.6
¾	5.939	8.639	19	283.52	59.69	48	1809.5	150.7	83	5410.6	260.7
3	7.068	9.424	½	298.64	61.26	49	1885.7	153.9	84	5541.7	263.8
¼	8.295	10.21	20	314.16	62.83	50	1963.5	157.0	85	5674.5	267.0
½	9.621	10.99	½	330.06	64.40	51	2042.8	160.2	86	5808.8	270.1
¾	11.044	11.78	21	346.36	65.97	52	2123.7	163.3	87	5944.6	273.3
4	12.566	12.56	½	363.05	67.54	53	2206.1	166.5	88	6082.1	276.4
½	15.904	14.13	22	380.13	69.11	54	2290.2	169.6	89	6221.1	270.6
5	19.635	15.70	½	397.60	70.68	55	2375.8	172.7	90	6361.7	282.7
½	23.758	17.27	23	415.47	72.25	56	2463.0	175.9	91	6503.8	285.8
6	28.274	18.84	½	433.73	73.82	57	2551.7	179.0	92	6647.6	289.0
½	33.183	20.42	24	452.39	75.39	58	2642.0	182.2	93	6792.9	292.1
7	38.484	21.99	½	471.43	76.96	59	2733.9	185.3	94	6939.7	295.3
½	44.178	23.56	25	490.87	78.54	60	2827.4	188.4	95	7088.2	298.4
8	50.265	25.13	26	530.93	81.68	61	2922.4	191.6	96	7238.2	301.5
½	56.745	26.70	27	572.55	84.82	62	3019.0	194.7	97	7389.8	304.7
9	63.617	28.27	28	615.75	87.96	63	3117.2	197.9	98	7542.9	307.8
½	70.882	29.84	29	660.52	91.10	64	3216.9	201.0	99	7697.7	311.0

RULES FOR USING PERCENTAGE

To find the *percentage* of any number when the *rate per cent is given*: Multiply the number by the rate per cent and set the decimal point two places to the left.

Example: Find 7.5 per cent of 35. 35 × 7.5 = 262.5, decimal point moved two places to the left gives Ans. 2.625.

To find what *rate per cent one number is of another*. Add two ciphers to the percentage and divide by the number on which the percentage is reckoned.

Example: What per cent of 75 tons is 9 tons? 900 ÷ 75 = 12 Ans. 12 per cent.

To find a number when the rate per cent and the percentage is known.—Add two ciphers to the percentage and divide by the rate per cent.

Example: If 68 pounds is 15 per cent of the entire charge, how many pounds in the total charge? Ans. 6800 ÷ 15 = 453.33 pounds.

To find what number is a certain per cent *more* or *less* than a given number.

When the given number is *more* than the required number add two ciphers to the number and divide by 100 plus the rate per cent.

Example: 465 is 35 per cent more than what number? 46500 ÷ (100 + 35) 135 = 344.4. Ans.

When the given number is *less* than the required number add two ciphers to the number and divide by 100 minus the rate per cent.

Example: 526 is 23 per cent less than what number? 52600 ÷ (100 − 23) 77 = 683.116. Ans.

CONVENIENT DATA FOR STORAGE CALCULATIONS

Cubic Measure

1728 cubic inches = 1 cubic foot.
27 cubic feet = 1 cubic yard.

Square Box Measure

A box 24 × 16 inches and 28 inches deep contains 1 barrel
" " 16 × 16¾ " " 8 " " " 1 bushel
" " 8¼ × 8¼ " " 4 " " " 1 gallon
" " 4 × 4¼ " " 4 " " " 1 quart

21 cubic feet of river sand will weigh 1 ton
22 " " " pit " " " 1 "
28 " " " stiff clay " " 1 "

USEFUL FACTORS

Inches × 0.08333 = feet
Square inches × 0.00695 = sq. feet
Cubic inches × 0.00058 = cu. feet
Cubic inches × 0.004329 = U. S. gallons
U. S. gallons of water × 8.33 = pounds
U. S. " " " × 231.00 = cu. inches
Pounds " " × 27.72 = cu. inches
Ounces " " × 1.735 = cu. inches

WEIGHT CALCULATIONS

Weight of round iron per foot = Square of diameter in quarter inches multiplied by .1666
Weight of flat iron per foot = Width × thickness × 10.3
Weight of plates per sq. ft. = 5 pounds for each ⅛ inch in thickness.
Weight of chain = Diameter squared × 10.7 (approximate).
Safe load (in pounds) for chain = Square of quarter inches in diameter of bar.

To compute weight of metal from weight of pattern; no allowance for cores or runners.

	Pattern of White Pine	Pattern of Mahogany
For Cast iron	× 16.7	× 10.7
" Brass	× 18.	× 12.2
" Lead	× 23.	× 15.
" Tin	× 15.	× 9.
" Zinc	× 16.	× 10.4

Weight of brass pattern × .9 = weight of iron casting approximately.

TABLE OF SPECIFIC GRAVITIES AND WEIGHTS OF METALS

Material	Specific Gravity	Weight per Cubic Inch (Pounds)
Water at 39.1 deg. F.	1.	.036
Aluminum	2.6	.094
Antimony, cast 6.64 to 6.74	6.7	.237
Bismuth	9.74	.352
Brass, cast 7.8 to 8.4	8.1	.30
Bronze 8.4 to 8.6	8.5	.305
Copper, cast 8.6 to 8.8	8.7	.32
Gold, pure, 24 carat	19.25	.70
Iron, cast 6.9 to 7.4	7.21	.263
Iron, wrought 7.6 to 7.9	7.77	.281
Lead	11.4	.41
Mercury at 60 deg. F.	13.58	.49
Platinum 21. to 22	21.5	.775
Silver	10.5	.386
Steel, average	7.8	.283
Spelter or Zinc 6.8 to 7.2	7.	.26
Tin, cast 7.2 to 7.5	7.35	.262

PRESSURE IN MOLDS

For depths below pouring basin varying from 1 inch to 12 feet.

Depth Ft.	Depth In.	Pressure Per Sq. In.	Depth Ft.	Depth In.	Pressure Per Sq. In.	Depth Ft.	Depth In.	Pressure Per Sq. In.
	1	.26		19	4.94	3	6	10.92
	2	.52		20	5.20	4		12.48
	3	.78		21	5.46	4	6	14.04
	4	1.04		22	5.72	5		15.60
	5	1.30		23	5.98	5	6	17.16
	6	1.56	2	00	6.24	6		18.72
	7	1.82		25	6.50	6	6	20.28
	8	2.08		26	6.76	7		21.84
	9	2.34		27	7.02	7	6	23.40
	10	2.60		28	7.28	8		24.96
	11	2.86		29	7.54	8	6	26.52
1	00	3.12	2	6	7.80	9		28.08
	13	3.38		31	8.06	9	6	29.64
	14	3.64		32	8.32	10		31.20
	15	3.90		33	8.58	10	6	32.76
	16	4.16		34	8.84	11		34.32
	17	4.42		35	9.10	11	6	35.88
1	6	4.68	3	00	9.36	12		37.44

To find total lifting pressure on cope multiply pressure per square inch at given depth below pouring basin by area (in sq. inches) of the surface acted against. The result will be in pounds.

TEMPERATURES

From Late Scientific Investigations.

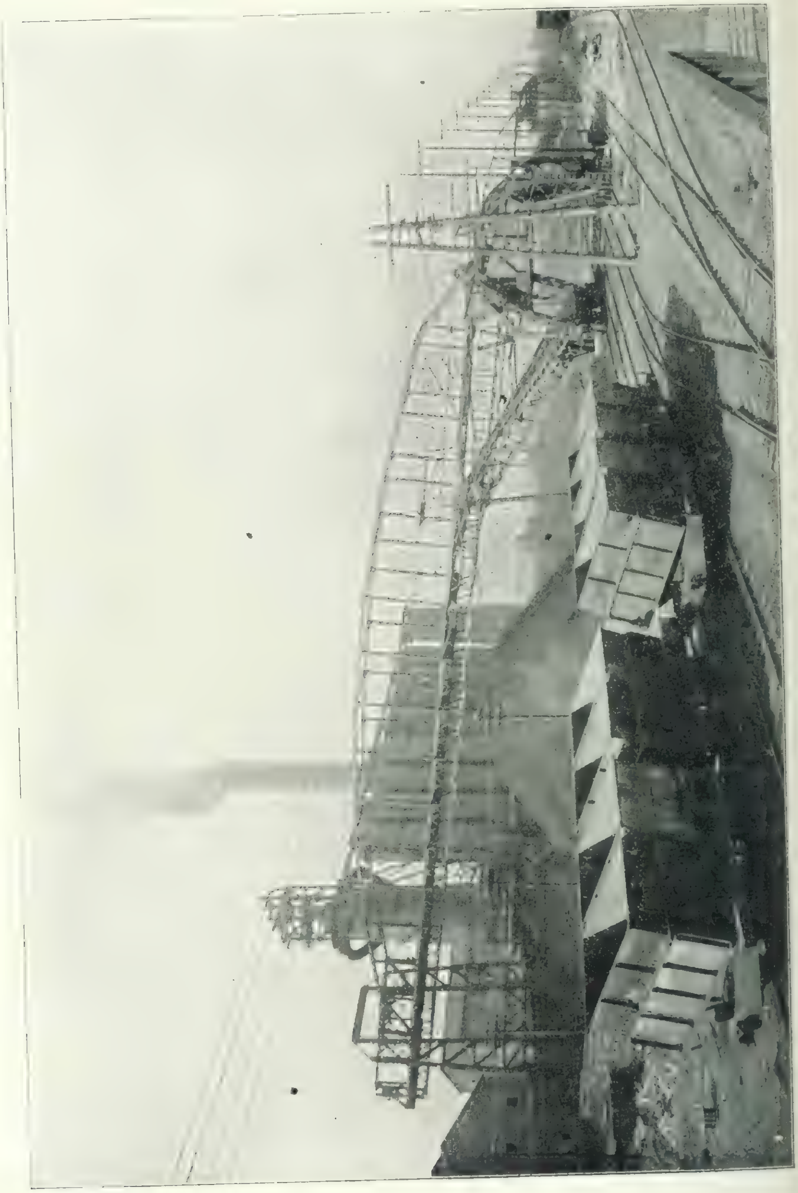
		Degrees Fahrenheit
Core ovens—approximate		250 to 450
Bright iron becomes	Yellow	435
	Purple	500
	Indigo	550
	Gray	750
Tin melts		445
Mercury boils		660
Lead melts		612
Zinc melts		775
Silver melts		1,775
Copper melts		1,885
Gold melts		1,900
Iron bar red in	a dark room just visible	950
	ordinary office	1,075
	daylight open air	1,450
Cast iron melts	white	2,075
	gray	2,230
Steel melts		2,750
Annealing malleable iron		1,600 to 1,750

AUTOMATIC APPLIANCES FOR HANDLING COAL AND IRON ORE.

During the past quarter of a century there has been a rapid, continuous, and truly phenomenal development in the means and methods for handling coal and iron ore in the transit from mine to furnace, or, in other words, from Mother Earth to the finished product. To so high a state of perfection have the utilities employed in the handling of these bulk commodities been brought, that the dawning years of the twentieth century find practically the entire movement from mine to market accomplished solely by mechanical means.

Surpassing as the achievements of the past score and a half of years have been in labor-saving, and consequently in the cost of handling iron ore and coal, they have not been more wonderful than the economies of time effected by the more rapid handling of the world's two most important minerals. It is indeed a great step from the old method of trundling small loads of the bulk material back and forth in wheelbarrows, to the new plan of transferring a carload of coal per minute, or to the moving of ore by means of grab buckets that scoop up automatically anywhere from two to ten tons at each operation; and yet, as has been said, less than thirty years has been required to work this amazing transformation.

The conditions governing the movement of iron ore and coal in the United States are peculiar in that several rehandlings are necessary. The major portion of the iron ore is mined in the States of Minnesota, Wisconsin, and Michigan; transported by rail to ports on Lakes Michigan and Superior; and then loaded on vessels which in some instances carry it to blast furnaces located directly on the shores of the inland seas, but which more frequently transport it to harbors on the south shore of Lake Erie, where there is a transfer from the vessels to railroad cars, in which the ore is moved to the blast furnaces of that great iron-manufacturing section known as the "Pittsburg District." Here, finally, there is still another rehandling when the ore which has been placed in stock piles is, as occasion requires, conveyed to the furnaces. The



HANDLING APPARATUS AT BLAST FURNACE

anthracite coal from the Pennsylvania field, and the bituminous fuel from the mines of Ohio, Pennsylvania, and neighboring States, which are shipped to points in the West and Northwest, traverse in the opposite direction practically the same route followed by the iron ore, and are subject to the same rehandlings.

The pioneer inventor who successfully solved the problem of handling coal and iron ore over a considerable range of distances solely or largely by mechanical means, was Mr. Alexander E. Brown, the well-known American engineer, the machines of whose invention are to this day accepted as the standard—and are indeed the sole—means of performing many of the functions in this highly specialized field.

BRIDGE TRAMWAYS.

At the outset, all the operations of transferring iron ore from ships to cars or stock piles, as the case might be, and of both loading and unloading coal-carrying vessels to and from cars or stock piles, were confined to a single class of apparatus—hoisting and conveying machinery of what is known as the "bridge tramway" type; and this form of handling appliance is yet so extensively used in moving both commodities as to merit first attention aside from its claim by reason of priority of invention.

A bridge tramway is, in effect, a miniature elevated railway along which loads are conveyed by the trolley system now so extensively employed in the industrial field. The skeleton bridge structure—supported at both ends by piers—is built of iron and steel designed to give the maximum strength with the minimum weight of material, and with all members made of such shapes, and so arranged in the trusses, as to offer the least possible surface to wind-pressure—an important consideration owing to the exposed locations in which these structures are generally used.

The bridge tramways proper usually range from 180 to 192 feet span; but, extending from the front pier, is a 34-foot apron reaching from the front of the dock out over the vessel tied up for unloading, while from the rear pier is a cantilever extension stretching back from 80 to 104 feet additional. Thus an area more than 300 feet wide is served by the tramway. The piers are of steel construction, and are high enough to support the bridge on an incline with the front end about 27 feet above the ground and the rear end 52 feet above the level. The piers are mounted on wheels running on tracks, so that the whole structure may be "skewed" or moved sideways back and forth along a dock to suit the hatches of a vessel. Thus a vessel may be unloaded by having several bridge tramways operating simultaneously over as many different hatchways, or openings in the deck; or the cargo may be removed by a single tramway adjusted so as to operate in first one division of the hold and then another, by means of the sidewise movement of the apparatus.

Running along a track suspended from the bridge between the girders, is a trolley with suspended bottom block and hook to which is attached the hoisting or pulling line, and all the motions of which are under perfect control of the operator by means of suitable levers. Up and down this trolley line, at a speed of hundreds of feet per minute, travels an iron tub or bucket in which the ore or coal is carried. These buckets are made in various sizes; but what might be termed the standard size has a capacity of seventeen cubic feet (or a gross ton) of ore.

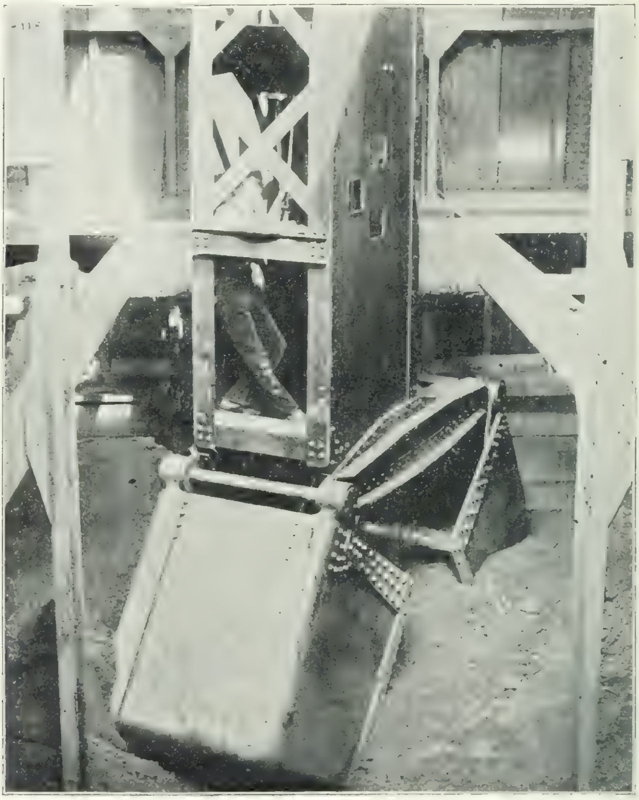
The plan of operation is practically the same in all cases. If coal or iron ore is being unloaded from a vessel, the operator, upon receiving from the hold of the vessel a signal that a tub is filled, throws the proper lever, and hoists the bucket at full speed through the hatch of the boat, the bottom block hooking automatically into the trolley, and the trolley carrying the heavily laden bucket to a point on the bridge or cantilever where its progress is arrested by dumping-irons placed at any desired location. These irons automatically trip the latch of the bucket, allowing it to upset, discharge its load, and automatically right itself. As soon as this is done, the operator releases the lever, and the bucket returns by gravity to its starting point in the hold of the vessel. The block unhooks automatically from the trolley, allowing the bucket to be lowered into the hold, whereupon the empty bucket is unhooked and a filled one hooked on. If preferred, the operator, instead of allowing the bucket to dump automatically, can lower it to any desired point for discharge, this being desirable when it is the purpose to transfer the coal or ore directly to waiting railroad cars.

One of the buckets such as have been described, will make a round trip from the hold of a vessel to the end of a bridge tramway trolley line, and return—a distance of 600 feet—in one minute; and in actual work a rate of forty-five seconds per round trip has been averaged for hours at a time. If the filling, handling, and hooking-on of buckets be done with reasonable dispatch, a single machine will readily transfer 400 gross tons of ore per day of ten hours. The cost of handling coal and ore by this means varies from seven-tenths of a cent to two cents per gross ton.

The first bridge tramway plants were erected on the iron-ore unloading docks at Cleveland, Ohio, about twenty-five years ago, and the new machines were for a time confined in their sphere of usefulness to the empire of the Great Lakes. Gradually, however, they secured general adoption, particularly for coal handling; and they are now to be found, not only on the Atlantic and Pacific coasts, but in Germany, Austria, Russia, Sweden, Egypt, and other foreign countries. Perhaps the best exemplification of the possibilities of this Yankee invention for coal handling, is afforded at the coaling stations of the United States Navy at Key West, Dry Tortugas, Mare Island, Cal., and New London, Conn., where, by means of bridge tramways such as have been described, fuel is transferred directly from storage buildings (having a capacity of 10,000 tons each) to the holds of United States war vessels.

GRAB BUCKETS.

During the early history of the bridge tramway plants, there was universal employment of tubs or buckets which, although self-dumping, had to be filled by hand. As an improvement upon these, there have been introduced various types of self-filling and automatic dumping buckets which will handle from two-thirds to four-fifths of a cargo or consignment of the balk material without hand-shoveling. The most primitive forms of these self-filling buckets were "shovel" buckets of five tons' capacity, which scooped up their load through being dragged against the slope of the coal or ore pile. Then came the "grab" buckets, descending with open jaws, which, closing, took from the ore or coal pile a "bite" of one ton or more and held the material securely until released at any desired point of discharge. This class of buckets was introduced, not only in connection with the familiar bridge tramways, but also in conjunction with wire-rope cableways. The latter have been utilized to some extent for coal and ore handling, in locations where the necessary span was greater than could be successfully covered by a suspension structure of the weight of a bridge tramway



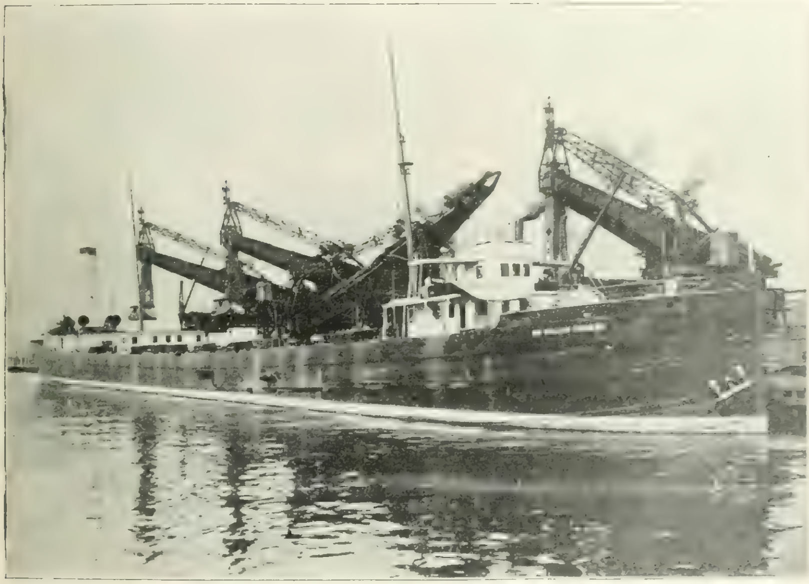
"CLAM-SHELL" BUCKET FOR AUTOMATIC UNLOADING.
Showing Operator in Mast.

CLAM-SHELL BUCKETS.

The most recent advances in ore-handling machinery have been along the development of appliances possessing the fundamental principle involved in the grab bucket above mentioned. The supreme triumph in this field is found in the recently devised automatic ore unloader, which, by means of a clam-shell attachment—an enlarged edition of the grab bucket—will take ten tons of ore from a ship's hold at each operation, and by means of which it is possible to remove every ounce of ore from a cargo-hold, thus dispensing entirely with hand shoveling, and eliminating the last utilization of manual labor in the handling of the raw material, from the time it is mined by means of a steam shovel until it is mechanically dumped into the blast furnace.

THE HULETT UNLOADER.

The Hulett automatic ore unloader, as the most perfect of these new appliances is known, is a machine which weighs fully 400 tons and has a height of 55 feet. It consists primarily of a foundation trestle, which is mounted upon wheels and which can be moved along the dock, the rails carrying the forward end of the trestle being directly on the brink of the dock, as in the case of the bridge tramways. Moving backward and forward on this foundation span, at right angles to the dock, is a heavy walking beam, attached to the outer end of which is the depending leg or



HULETT AUTOMATIC ORE UNLOADERS TAKING ORE FROM A LAKE VESSEL.

mast that carries the clam-shell bucket used in dipping out the ore. The parallel motion keeps the leg always in a vertical position; and the weight of the end of the walking beam, from which the bucket is suspended, is counterbalanced by means of a hydraulic accumulator located at the opposite end.

To operate this ingenious apparatus, the walking beam is run forward until the depending leg is suspended directly over the deck of the vessel. Then the mast, which revolves in a complete circle and in which the operator is stationed, is lowered through a hatchway and turned in any direction, its radius being fully nine feet. When open, the clam-shell bucket has a spread of 19 feet. After the bucket has been closed by hydraulic power, it is lifted from the boat and run back over the dock, where its contents can, if desired, be discharged directly into the railroad cars which are to convey the ore to the blast furnaces. Only three men are required to operate one of these machines, which has a capacity of 250 tons per hour.

The world's record for the rapid handling of an ore cargo was made a short time ago at the port of Conneaut, Ohio, when four of these machines, in a total working time of 4 hours 43 minutes, removed from the steamer *James H. Hoyt* a cargo of 5,300 tons of ore. All the cargo was taken out by the machines, no cleaning up whatever by hand labor being necessary.

FURNACE HOISTS.

The usefulness of new marvels for handling bulk materials is by no means confined to the transfer of coal and iron ore to and from ships, railroad cars, and stock piles, but is demonstrated in scarcely a less striking manner at blast furnaces and iron and steel making plants in general. Foremost among the utilities in this field is the furnace hoist and stock-distributer, which has done away entirely with the old-time dangerous and unsatisfactory method of feeding blast furnaces, and, by automatically charging the furnaces, dispenses entirely with the employment of top-fillers.

This hoist consists, in the main, of an inclined steel-trussed bridge starting from a pit and reaching to the top of the shell of the furnace, where it terminates in an extension over the top of the bell and hopper. A skip car with a capacity of from 2,000 to 6,000 pounds is arranged to run on this track, the hoist rope passing over the top sheave and back to the drum of the hoisting engine near the incline. When the skip car loaded with iron ore, coke, or limestone, as the case may be, arrives at the top of the furnace, the car is automatically tipped, and the load is dumped into the great receptacle, from which the belt has been automatically lifted for the purpose.

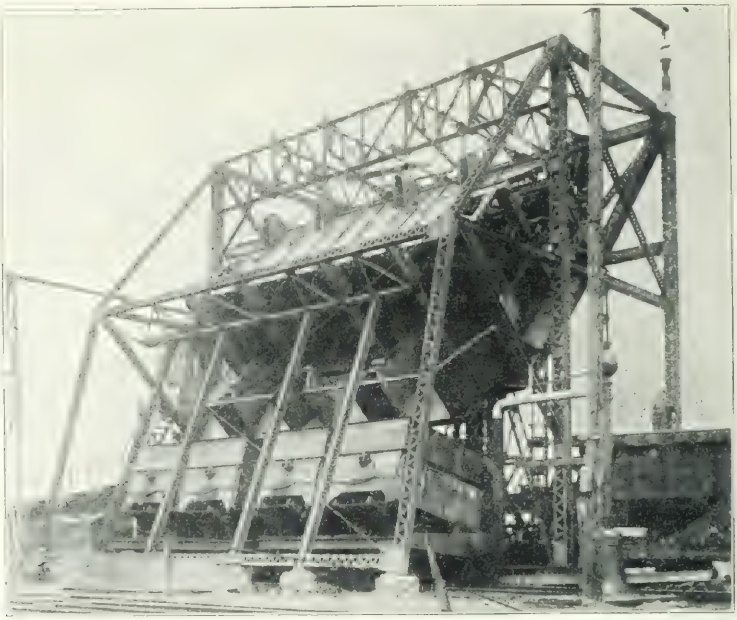
At all blast furnaces the transfer of iron ore from stock or storage piles to furnace as the raw material is required for consumption, constitutes a handling problem of some complexity. In this work there are employed steam shovels, locomotive derricks equipped with grab buckets, and, finally, various modifications of the bridge tramway. Some of the bridges thus employed have a clear span of about 250 feet over storage yard and railroad tracks, thus enabling the ore to be handled directly from railroad cars to furnaces, or from the stock piles where the surplus supply is held.

CAR-DUMPING MACHINES.

Yet another form of apparatus which is being employed in handling both coal and iron ore, is the car-dumping machine. At the furnaces these dumpers are utilized in some instances to transfer the contents of standard-sized railroad cars to smaller cars which carry the material to the furnaces; but the true province of this type of apparatus is in transferring coal (for water shipment) from cars to colliers. In this field they have found extensive utilization.

There are many different designs of car-dumping machines; but the most efficient styles are those which pick up and completely overturn the loaded car, transferring its contents to the hold of the vessel to be loaded. The earliest forms of car dumpers, while entirely satisfactory in the rapidity with which they handled material, were considered deficient in that they entailed a serious breakage of the coal. This, however, was finally remedied by modifications whereby the coal is dumped into pans connected with chutes leading to the vessel, which not only enable the fuel to be handled with far less breakage than formerly, but also make it possible to direct the influx to any portion of the hold desired.

The fundamental feature of the average car dumping machine is a car-tipping device or cradle into which the car is run and then

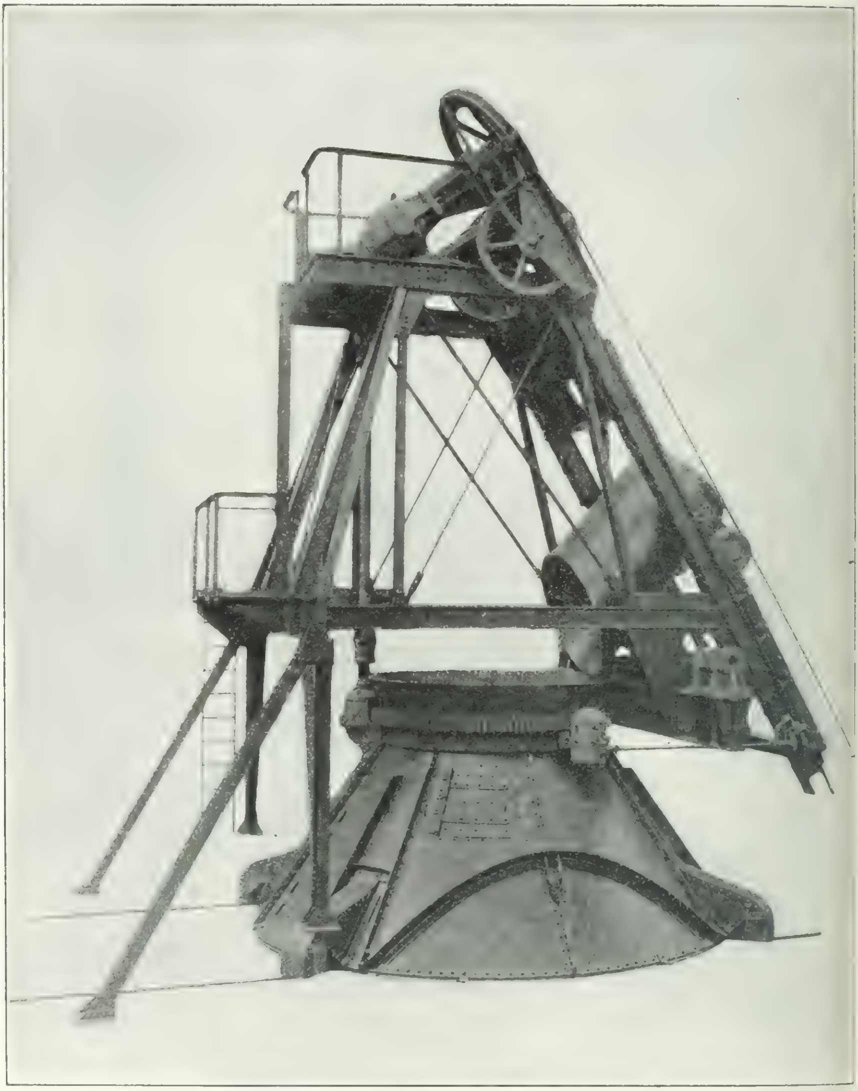


A MODERN CAR-DUMPING MACHINE.

clamped, and which turns over with the car and discharges its contents. In some machines the receiving pan is automatically tilted at an angle proportionate to that of the car-tipping device, so that the coal slides gradually instead of pouring or falling; and in certain machines the coal is not sent into the vessel hold through a chute, but is transferred from the car, as it is dumped, to transfer tubs or to steel buckets arranged on the endless-chain plan, which convey it to the cargo space by easy stages and with practically no breakage. Some of these car-dumping machines will handle upward of 200 loaded cars in an ordinary working day, not only actually transferring the coal, but handling the loaded and empty cars to and from the machine, and obviating all necessity for the employment of a shifting engine and train-crew.

COAL-LOADING MACHINES.

An ingenious type of coal-loading machine is found at Fairport on the south shore of Lake Erie, and at several other points in the United States. By its operation the coal to be loaded on a boat is dumped from the hopper-bottomed railroad cars into a large receiving hopper underneath the car. From this hopper the fuel is delivered to a carrier of the continuous type, which hoists it up to an incline spout down which it passes into a telescope spout and thus directly into the boat. This telescope spout is drawn out to its full length at the commencement of operations, and is then gradually taken up or shortened as the boat is filled. By this means the spout is kept constantly full of coal, and the breakage of the fuel is reduced to a minimum. It requires but two men to operate such a machine, which is driven by a 50-horse-power engine. The cost of an installation of this kind is much less than in the case of some of the other types of coal-handling machinery, and yet such a machine is capable of loading from 600 to 900 tons of coal per hour.



FURNACE-HOIST AND STOCK DISTRIBUTOR.

Showing Skip-Car Dumping into Distributor.

Brown Hoisting Machinery Co.

MECHANISM

The study of mechanism is the study of the laws that govern the motions and forces in machinery. Pure mechanism deals only with the amount and kind of motions, without regard to the forces transmitted, and in this instruction paper only this branch of the subject will be considered. That is, we shall study how to proportion the parts to get the proper motions. Knowing this, the principles of machine design and strength of materials will teach us how large the parts must be to stand the stresses which come upon them.

A Mechanism is a group of parts so shaped and arranged that a definite motion of one part will give other definite motions to the other parts.

A Machine is a combination of mechanisms each of which may be doing a different kind of work, but the whole combination of mechanisms working together accomplishes some desired result. Take for example, a metal planer; the result which is to be accomplished is the planing of a piece of metal, but in order to do this, several auxiliary results must be accomplished. The table or platen, to which the metal is fastened must be moved back and forth, the tool must be fed forward after each chip has been cut, and various other motions produced. There are certain pieces in the planer whose sole work is the moving of the platen, and all these pieces taken together form one mechanism; in like manner, there are certain parts whose sole work is feeding the tool forward each time, and all these parts taken together form another mechanism. All the mechanisms when brought together form the machine.

MOTION.

An object which is changing its position is said to be in motion and an object which is not changing its position is at rest.

Absolute and Relative Motion. If a man is moving along in a sail boat without changing his position in the boat, both man and boat have what is usually spoken of as absolute motion, that is, they are both changing their position with respect to the earth and water around them. They both change their position in the same direction and at the same rate however, so that they are at rest with respect to each other. If now, the man should start to walk forward in the boat, he would change his position with respect to surrounding objects faster than the boat and he would have motion relative to the boat. We thus have two kinds of motion, absolute and relative; absolute motion being the motion of a body with respect to some fixed object, and relative motion being the motion of one moving body with respect to another moving body.

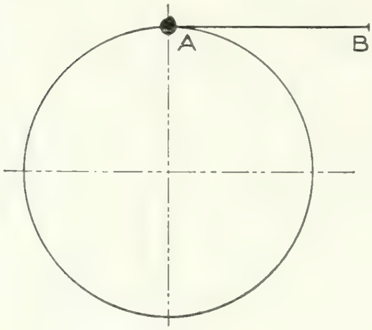


Fig. 1.

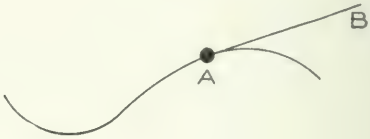


Fig. 2.

Since every object has more or less size and therefore can not be represented on paper as readily as can some particular point or line in the body, as far as possible in our study of the motions of bodies we shall consider points and lines, in place of the bodies themselves.

Velocity is the rate of motion. If a bullet travels through the air at the rate of one hundred feet in a second, it has a velocity of one hundred feet per second.

Direction of Motion. A point may have motion in a straight line, in a circle, or in any other curve. The tendency of any body which is in motion is to continue to move in a straight line unless caused to leave that path by some force applied to the body The direction of the straight line in which a point is moving is called the direction of motion of the point. If an object is traveling in a circle, the direction of its motion at any given instant is the straight line tangent to the circle at the point where the object is at the given instant. For example, if the point A, Fig. 1, is moving around the circle, the direction of its motion, when in the position shown, is the line AB. In the same way in Fig. 2, if the point A is moving in the curved path, its direction when in the position indicated is the line AB.

By choosing a convenient scale, as one inch equals one foot, or one inch equals ten feet, etc., depending upon how large the velocities are with which we have to deal, the line may be drawn of a length that will represent the velocity of the point A. Suppose the circle, Fig. 1, to have a circumference of ten inches, and suppose the point A to be traveling around the circle at such a speed that it goes around once in five seconds; then, since it travels ten inches in five seconds, it has a velocity of two inches per second. Accordingly, if we draw the line AB two inches long, tangent to the circle at any given position of A, the line AB represents the direction and velocity of A at the instant under consideration. Of course, the direction of motion of a point which is moving in any path other than a straight line is constantly changing, but the direction in which it is moving at a given instant is the direction which it would take if the forces which constrain it to move in the curved path were removed at that instant.

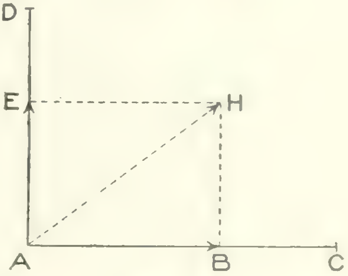


Fig. 3.

Composite Motions. In Fig. 3, let A represent a body lying on a table; suppose AC and AD are strings making a right angle with each other. First, let the string AC be pulled with such force that it will cause A to move one inch in the direction AC, in one second; then A will be at B at the end of a second, the line AB representing the direction and velocity of A when the string AC is pulled. Next, suppose the body to be back in its original position A, and that the string AD is pulled with such force that it will cause A to move $\frac{3}{4}$ of an inch in the direction AD in one second; then at the end of a second A will be at E, the line AE representing the direction and velocity of the body when the string AD is pulled.

Again, suppose both strings to be pulled at the same time, with the same force as before. Then the pull on AC will still cause A to move toward C with a velocity AB, and the pull on AD will cause A to move toward D with a velocity AE, so that at the end of a second the body will be at neither E nor B, but at some point H, whose position is at a distance BH from B, the line BH being equal and parallel to AE. The point H is also at a distance EH from E, the line EH being equal and parallel to AB. In other words, the path over which the body has moved is the line AH, which is the diagonal of a parallelogram whose sides are equal to AB and AE respectively. The lines AB and AE, which represent the velocities caused by the pulls on the respective strings, must be drawn to the same scale, that is, if the pull on AC causes a velocity of one inch per second and the pull on AD causes a velocity of $\frac{3}{4}$ inch per second, AE must be $\frac{3}{4}$ as long as AB.

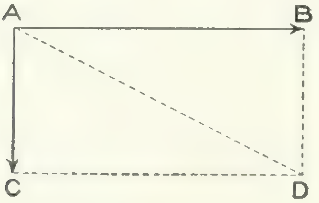


Fig. 4.

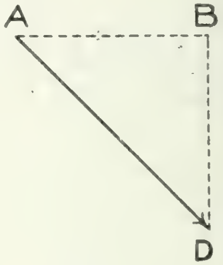
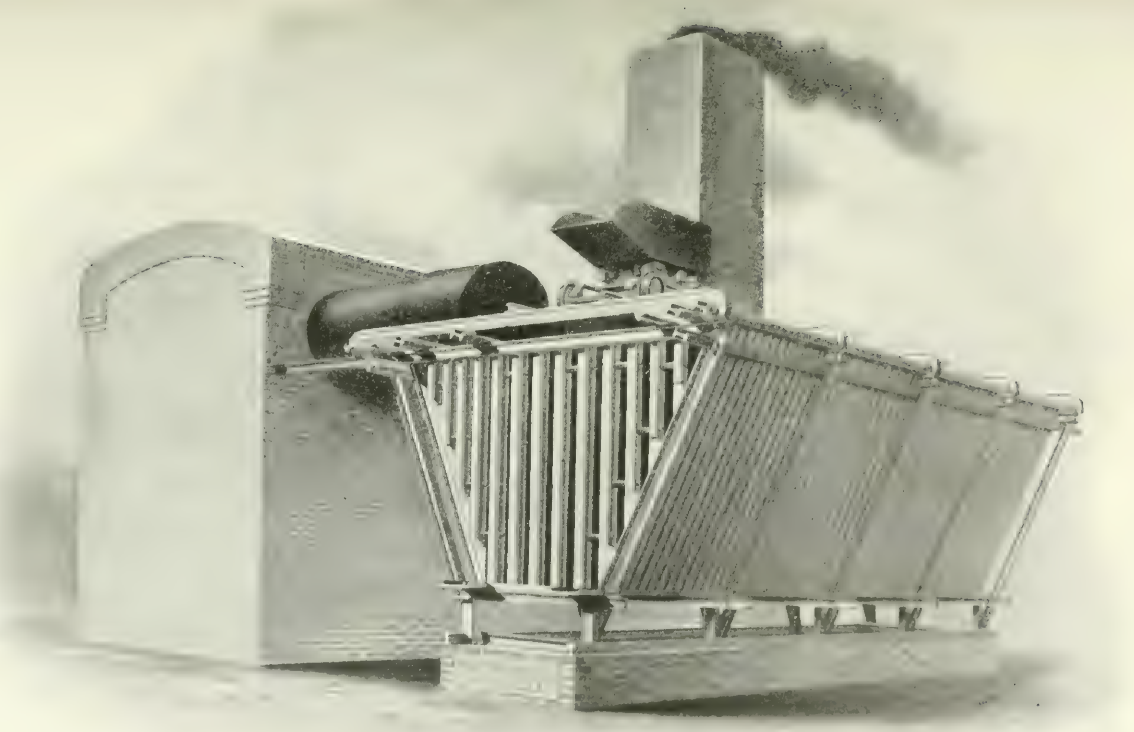


Fig. 5.

The velocities AB and AE are called *component velocities*, and the velocity AH the *resultant*.

Let us take another example. Suppose a ball is thrown toward the east with a velocity of ten feet per second, and the wind carries the ball toward the south with a velocity of five feet per second. Let us find graphically how fast and in what direction the ball is actually moving. Using any convenient scale, draw the line AB, Fig. 4, to represent ten feet, and the line AC to represent five feet at the same scale, AC being at right angles to AB, since south is at right angles to east. From C draw CD parallel to AB, and from B draw BD parallel to AC meeting CD at D; then AD, the diagonal of the rectangle thus formed, gives the



THE GUYER DESULPHURIZING KILN—24 FOOT SECTION
Allis-Chalmers Co.

direction and the velocity, at the same scale as before, of the actual motion of the ball.

The preceding process is called *composition* of velocities; that is, if we know the velocity of a body in two directions at right angles to each other, we can find from these the real velocity and direction of the motion. Quite as frequently we have given the real direction and velocity and wish to find the velocity parallel and at right angles to some given line. Thus, suppose we know that a ball is moving at a speed of one hundred feet per minute toward the southeast and we wish to know how fast it is moving towards the east. Draw the line AD, Fig. 5, to represent one hundred feet, at a convenient scale; then draw the line AB, making with AD the same angle that a line running southeast makes with a line running east (that is, 45 degrees). From D draw DB perpendicular to AB, meeting AB at B; the length of AB represents, at the same scale at which AD was drawn, the velocity of the ball in an easterly direction, and BD represents its velocity in a southern direction. This is called the *resolution* of velocities, the velocity AD being resolved into two components, one in the direction AB, and one perpendicular to this direction.

*EXAMPLES FOR PRACTICE.

1. If a steamer travels 91,200 feet per hour, what is the velocity in feet per second?

Ans. 25.33 feet.

2. If the piston of an engine moves at the rate of 12.5 feet per second, what is the piston speed in feet per minute?

Ans. 750 feet.

3. A steamer is moving eastward at a speed of 800 feet per minute and the wind and tide carry it north at the rate of 100 feet per minute. Find graphically how fast and in what direction the steamer is actually moving.

Ans. 810 feet per minute.

4. A ball is thrown, with a velocity of 50 feet per second, across a stream 100 feet wide. The wind carries the ball up stream 10 feet per second. How far up stream from the point at which the ball was aimed will it strike? Ans. 20 feet.

*NOTE. Problems 3, 4, 5 and 6 are to be solved graphically.

5. A platform is set up at an angle of 30 degrees with the horizontal, and a weight is allowed to slide down the platform at a speed of ten feet per second. How long will it take the weight to get 10 feet below the point from which it started?

Ans. 2 seconds.

6. The horizontal component of the velocity of a body is 26 feet per minute. If the actual velocity is 52 feet per minute find graphically the vertical component.

Ans. 45 feet per minute (about).

7. A man is on a railway train which is moving at the rate of 25 miles per hour and walks toward the rear of the train at the rate of 88 feet per minute. How fast is the man actually moving?

Ans. 24 miles per hour.

Temporary Center of Revolution. In Fig. 6, let AB represent a bar that forms some part of a mechanism, and suppose that for the moment the end B has a velocity in the direction of and equal to BD, and that the end A has a velocity in the direction of and equal to AC. As the whole rod, for the instant, is moving as if it were revolving about a center, the actual velocities of the various points in the rod are proportional to their distances from the center. To find the center for the case shown, draw the lines AT and BT perpendicular to AC and BD, respectively, until they meet at T, which is the center about which the whole rod may be considered to be revolving. The velocities AC and BD cannot be chosen at random, but must be such that BF is equal to AE; that is, their components in the direction of AB must be equal.

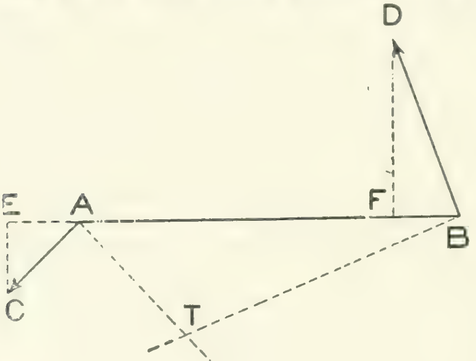


Fig. 6.

REVOLVING BODIES.

One of the most common motions which is found in machinery of all kinds is the motion of revolution, that is, the motion of a body turning around a center or axis. The axis may pass through the body itself or it may lie entirely outside the body. Fig. 7 is an example of the first case, where the cylinder is revolving about the shaft A, which passes through the center of the cylinder. Fig. 8 is an example of the second case where the block B is revolving about the shaft A.

The speed of revolution of a body is generally described by giving its number of revolutions per minute, which is abbreviated to R. P. M.

We will use the following abbreviations throughout this instruction paper: d = diameter; r = radius or distance of a point from the center about which it is revolving, and π (pronounced Pi) = 3.1416.

Let us consider a point C on the circumference of the cylinder in Fig. 7. For every complete revolution of the cylinder the point C travels through the air a distance equal to the circumference of the cylinder, or, since the circumference of a cylinder is 3.1416 times its diameter, the point C will travel 3.1416 times the diameter of the cylinder. Therefore the actual velocity through the air or **linear velocity** as it is termed, of a point on the circumference of a revolving cylinder is equal to the diameter of cylinder times 3.1416 times the number of revolutions in a unit of time.

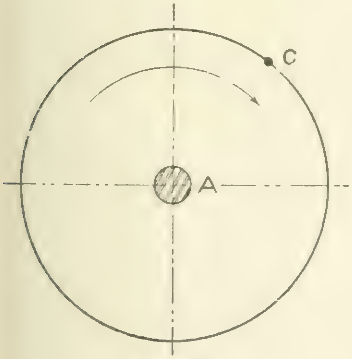


Fig. 7.

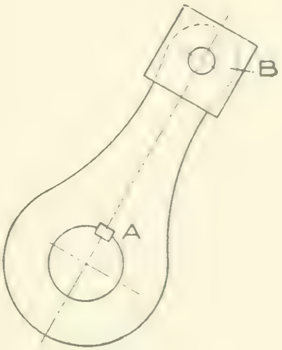


Fig 8.

If we assume a foot as our unit of distance and a minute as our unit of time, the above principle may be stated as a formula:

$$\text{Linear Velocity} = \pi\, d \text{ times R. P. M.} \qquad (1)$$

$$\text{or} \quad \text{“} \qquad \text{“} \quad = 2\,\pi\, r \text{ times R. P. M.} \qquad (2)$$

This will give the linear velocity in feet per minute and to use this formula the diameter or radius must be expressed in feet or fractions of a foot. If d or r is in inches, the linear velocity will be in inches. If linear velocity per second is desired, the number of revolutions per second must be used instead of R. P. M. From this formula we see that the linear velocity varies directly as the diameter or radius, and also directly as the number of revolutions.

The following examples will illustrate the use of the above formula:

If a fly wheel is 10 feet in diameter and makes 75 revolutions per minute, how fast is a point on its circumference moving? Using formula (1),

$$\begin{aligned}\text{Linear Velocity} &= \pi\, d \times \text{R. P. M.}\\ &= 3.1416 \times 10 \times 75.\\ &= 2356.2 \text{ feet per minute.}\end{aligned}$$

Therefore a point on the circumference of the fly wheel is moving at the rate of 2356.2 feet per minute.

Suppose that the center of the block B, Fig. 8, is at a distance of 18 inches from the center of the shaft A and that the arm turns around the shaft 60 times per minute. To find the linear velocity of the center of block B, we must first reduce the 18 inches to feet. Then,

$$\begin{aligned}\text{Linear Velocity} &= 2 \times 3.1416 \times 1.5 \times 60.\\ &= 565.49 \text{ feet per minute.}\end{aligned}$$

The same formula may be used to find the diameter or radius when the linear velocity and revolutions are given, or to find the revolutions when the linear velocity and diameter or radius are given. To do this, substitute the known quantities in the equation and solve by Algebra to find the unknown quantity. Let V = Linear Velocity.

Linear Velocity: $V = \pi d \times \text{R. P. M.}$

Diameter: $d = \dfrac{V}{\pi \times \text{R. P. M.}}$

Revolutions: $\text{R. P. M.} = \dfrac{V}{\pi d}.$

EXAMPLES FOR PRACTICE.

1. Find the linear velocity of a point on the rim of a fly wheel making 120 revolutions per minute. Assume fly wheel to be 7 feet in diameter. Ans. 2638.9 feet.

2. How many turns will a 6-foot wheel make while going one mile?

Ans. 280.

3. A locomotive is running at the rate of 40 miles per hour. How many revolutions are the $6\frac{1}{2}$-foot drivers making per minute?

Ans. 172.

4. The drivers of a locomotive are $5\frac{1}{2}$ feet in diameter. The crank pin is twelve inches from the center of the wheel. Find the linear velocity in feet per second of the crank pin if the engine makes 25 miles per hour. Ans. 13.32.

CYLINDERS AND CONES REVOLVING IN CONTACT.

When two cylinders are arranged to revolve upon parallel axes which are at a distance apart just equal to the sum of the radii of the two cylinders, their circumferences will touch along one line, and if both cylinders revolve and we assume that there is no slipping of one surface on the other, the surface velocities of their circumferences must be equal, that is, the linear velocity of any point on the surface of one would be the same as the linear velocity of any point on the surface of the other. Then, if in Fig. 9, we let S equal the surface velocity of the cylinders, C the radius of cylinder A, D the radius of B, M the revolutions per minute of A, and N the revolutions per minute of B, we can obtain the following equations by substituting these values in formula (2):—

$$S = 2\pi C \times M.$$
$$S = 2\pi D \times N.$$

and dividing the first by the second we have:

$$\frac{S}{S} = \frac{2\pi C \times M}{2\pi D \times N} \text{ or } 1 = \frac{C\,M}{D\,N}$$

therefore $D\,N = C\,M$ or $D \times N = C \times M$.

According to ratio and proportion in Algebra,

$$\frac{M}{N} = \frac{D}{C} \tag{3}$$

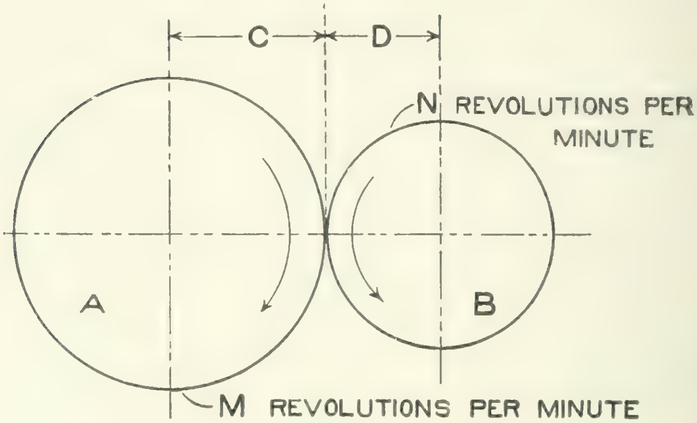


Fig. 9.

This may be stated as follows:—

$$\frac{\text{Revolutions of Driver}}{\text{Revolutions of Driven}} = \frac{\text{Radius of Driven}}{\text{Radius of Driver}}$$

That is, the numbers of revolutions are to each other inversely as the radii, and therefore as the diameters.

Two cylinders revolving in contact, without slipping, revolve in opposite directions; that is, if A revolves right-handed (like the hands of a clock), B will revolve left-handed. This is indicated by the arrows in Fig. 9.

The following examples will illustrate the method of calculation for speeds of cylinders, according to the preceeding discussion. Suppose a wheel A, 2 feet in diameter, is revolving with its surface in contact with the surface of another wheel B. A makes

25 R. P. M. Assuming that no slipping occurs between the surfaces of the two wheels, what must be the diameter of B in order that it shall make 75 R. P. M.? From the formula (3) we have

$$\frac{\text{Diameter of B}}{\text{Diameter of A}} = \frac{\text{R. P. M. of A}}{\text{R. P. M. of B}}$$

or

$$\frac{\text{Diameter of B}}{\text{2 feet}} = \frac{25}{75}$$

$$\text{Diameter of B} \times 75 = 2 \times 25$$

therefore Diameter of B $= \frac{2}{3}$ feet $= 8$ inches.

The same principles apply to cones which are revolving in contact. Let Fig. 10 represent the side view of two right cones which are in contact along the line EF, which is an element common to both. Then

$$\frac{\text{R. P. M. of A}}{\text{R. P. M. of B}} = \frac{FG}{FH} \qquad (4)$$

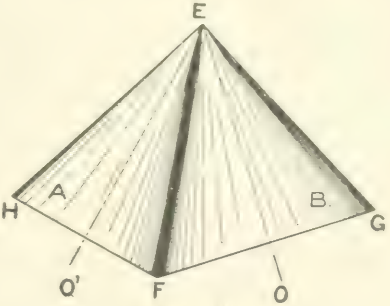


Fig. 10.

That is, their revolutions are to each other inversely as the diameters of their bases. If the angles OEF and O'EF are known, instead of the diameters of the bases, the ratio of the number of revolutions may be found from the following trigonometric formula:

$$\frac{\text{R. P. M. of A}}{\text{R. P. M. of B}} = \frac{\text{Sine of angle OEF}}{\text{Sine of angle O'EF}} \qquad (5)$$

If the angle between the axes OE and O'E is given and it is desired to find the relative sizes of the two cones whose revolutions shall have a given ratio, the angles OEF and O'EF could be calculated, but the calculation would be rather difficult and therefore a solution which is partly graphical is more convenient and usually sufficiently accurate.

Let EO' and EO Fig. 11, be the center lines of two shafts which lie in the same plane and make an angle of 45 degrees with each other. The shafts are to be connected by two rolling cones so that the shaft O′E shall make 30 revolutions while the shaft OE makes 40. The base of the larger cone is 12 inches, to find the base of the smaller cone and the altitude of both. Since, from the preceding discussion, the speeds are inversely as the diameters of the cones, the larger cone must be on the shaft which is making the fewer number of revolutions, that is, O′E.

Then from formula (4).

$$\frac{\text{Speed of O}'\text{E}}{\text{Speed of O E}} = \frac{\text{Diameter of base of cone on O E}}{\text{Diameter of base of cone on O}'\text{E}}$$

$$\frac{3}{4} = \frac{\text{Diameter of base of cone on OE}}{12}$$

Solving the equation we get

Diameter of base of cone OE = 9 inches.

Now draw the line PN parallel to O′E and at a distance from O′E equal to the radius of the base of the cone O′E (in this case 6 inches), at a convenient scale, and draw the line ML parallel to OE and at a distance equal to the radius of the base of the cone on OE (in this case $4\frac{1}{2}$ inches). These lines intersect at the point C. A line from C to E is the element along which the cones touch each other. From C draw lines perpendicular to OE and O′E, meeting them at S and R respectively. Then SE and RE are the altitudes. To draw the cones, lay off ST equal to CS, and RV equal to CR. Join E with T and V and the cones are complete.

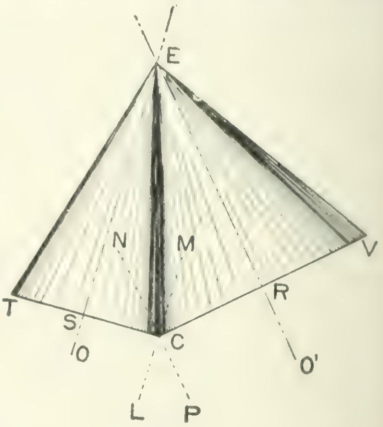


Fig. 11.

CYLINDERS AND CONES CONNECTED BY BELTS.

Frequently two shafts must be connected so that one may drive the other, and yet they are so far apart that cylinders cannot be placed on them which will touch each other. In this case it is customary to place on each shaft a cylinder, or pulley, and over

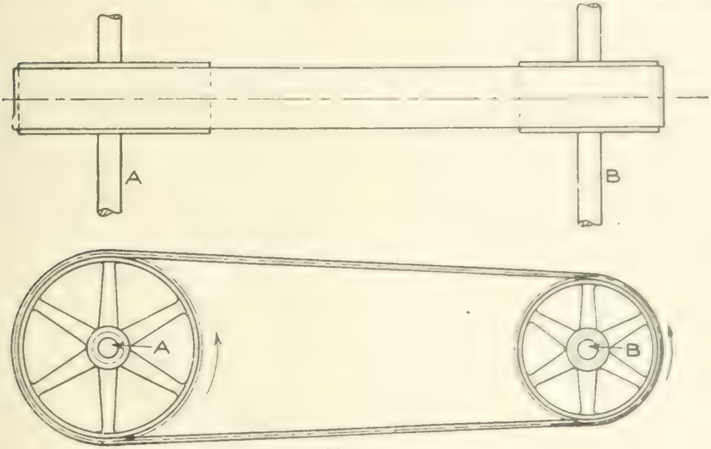


Fig 12.

these pulleys stretch a band, or belt made of some flexible material. The pulleys are fastened to the shafts so that the pulley and its shaft turn together, and the belt is stretched over the pulleys tight enough so that the friction between the belt and the surface

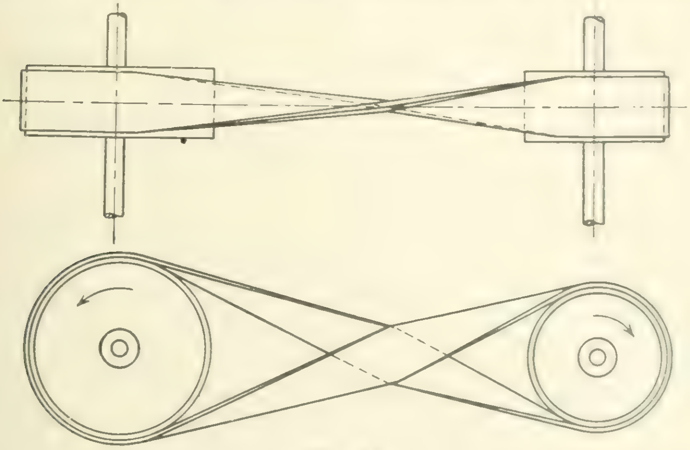


Fig. 13.

of the pulley is sufficient to make them travel with the same linear velocity. A detailed study of the exact manner of finding the proper locations of the pulleys and drawing the pulleys and belts can be found in Mechanical Drawing Part V, so that we will now study only the general principles involved, particularly with reference to making the necessary calculations.

The principles which we learned above, concerning the relative speeds of two cylinders in contact, apply also to two pulleys connected by a belt. The rule governing the direction of rotation, however, is different. When the connection is made by means of a belt, the relation of the directions of rotation depends upon the way the belt is put around the pulleys. If the belt is put on as shown in Fig. 12, known as open belt, the pulleys will turn in the same direction. If the belt is as shown in Fig. 13, known as a crossed belt, the pulleys will turn in opposite directions.

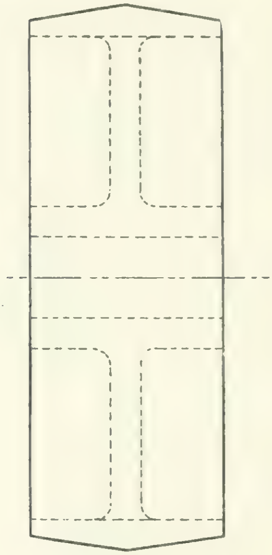


Fig. 14.

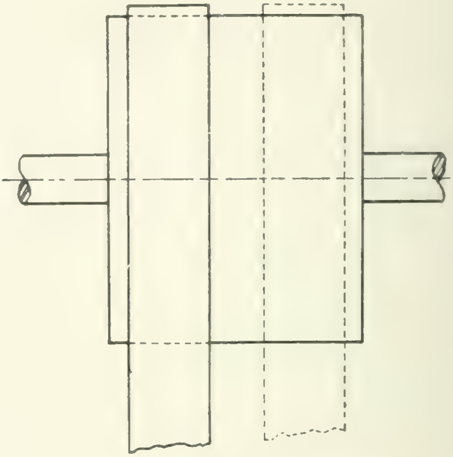


Fig. 15.

Crowning Pulleys. The outer surface of pulleys, instead of being made cylindrical is often made of larger diameter in the middle, as shown in Fig. 14. A pulley having this increase of diameter in the middle is said to have a crowned face. The object of the crowning is to help the belt to remain on the pulley. A belt will always run to the part of the pulley which is largest in diameter; therefore, if the diameter increases towards the middle, the belt will tend to run to the middle, and will be less likely to slip off. If the belt is to be at different places on the pulley at different times, as indicated by the full and dotted positions in Fig. 15, the surface cannot be crowned, but must be cylindrical.

As problems similar to the following often arise, this one should be studied carefully until every step is understood. In Fig. 16, A is a shaft turning 60 R. P. M. in the direction indicated by the arrow. B and C are cylinders over which a strand of cloth is to pass as indicated, the cloth passing over the top of B and under the bottom of C. In order that B and C may revolve in proper direction a crossed belt must be used between A and C, as shown. B is 24 inches in diameter, C is 18 inches in diameter, and the cloth is to travel at the rate of 120 feet per minute. E is a pulley 15 inches in diameter, which drives the pulley D, on the same shaft as B. F is a pulley 18 inches in diameter, driving pulley, G, on the same shaft as C. The problem is to find the number of revolutions of B and C, and the diameters of D and G.

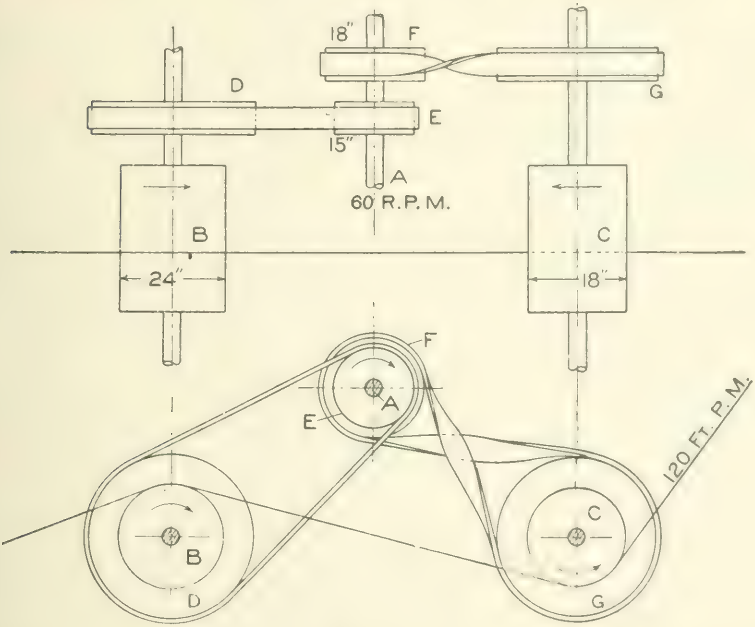


Fig. 16.

The circumference of B = 24 inches × π = 2 feet × π = 6.2832 feet. Therefore, its surface velocity if it made one R. P. M. would be 6.2832 feet per minute. But since it is to have a surface velocity = 120 feet per minute (equal to that of the cloth) its speed must be 120 divided by 6.2832 = 19.1 R. P. M. Revolutions of C are found in the same way.

18 inches = 1.5 feet. 1.5 feet × 3.1416 = 4.7124 feet = surface speed.

120 divided by 4.7124 = 25.4 R. P. M.

Now from formula (3):

$$\frac{\text{Revs. of D}}{\text{Revs. of E}} = \frac{\text{Diameter of E}}{\text{Diameter of D}}$$

and since the revolutions of D = the revolutions of B

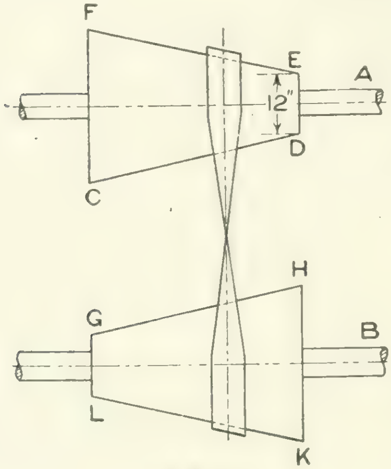


Fig. 17.

$$\frac{19.1}{60} = \frac{15}{x}$$

$$19.1\,x = 15 \times 60$$

$$x = 47.12 +$$

therefore, pulley D is $47\frac{1}{8}$ inches in diameter.

$$\frac{\text{Revs. of G}}{\text{Revs. of F}} = \frac{\text{Diameter of F}}{\text{Diameter of G}}$$

$$\frac{25.4}{60} = \frac{18}{x}$$

$$25.4\,x = 18 \times 60$$

$$x = 42.5 \text{ (approx.)}$$

therefore, pulley G is 42.5 inches in diameter.

Taper Cones. Suppose two equal frustums of cones are arranged on parallel shafts, as shown in Fig. 17. Shaft A, turning at a constant speed, can be made to drive shaft B at different speeds by changing the location of the belt on the cones. In order to use cones with a straight taper, a crossed belt should be used. If an open belt is used, the cones should be shaped as shown in Fig. 18. It is necessary to give this curvature to the face in order to keep the same tension on the belt for different positions. With a crossed belt this condition is fulfilled by making the face a straight line. If the shafts are far apart, the straight cones are sometimes used for an open belt.

Since the calculations for finding the proper shape of the cones for an open belt are difficult and are not often needed, we will give our attention only to the straight cones for a crossed belt.

In Fig. 17 let shaft A be the driver, turning at a constant speed of 100 R. P. M. The small end of the cone on A is 12 inches in diameter. We wish to find the diameter of the large end of the cone on B, in order that the slowest speed of B may be 75 R. P. M. Then, if the cones are alike, to find the greatest speed of B:

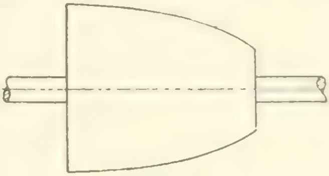


Fig. 18.

$$\text{First}\qquad \frac{\text{R. P. M. of A}}{\text{R. P. M. of B}} = \frac{HK}{ED}$$

$$\frac{100}{75} = \frac{HK}{12}$$

$$75\,HK = 12 \times 100$$

$$\text{Therefore } HK = \frac{1200}{75} = 16 \text{ inches.}$$

Now, if the cones are equal

$$\text{and}\qquad \begin{aligned} GL &= ED = 12 \\ FC &= HK = 16. \end{aligned}$$

$$\text{Then}\qquad \frac{\text{R. P. M. of A}}{\text{R. P. M. of B}} = \frac{GL}{FC}$$

$$\frac{100}{x} = \frac{12}{16}$$

$$x = \frac{1600}{12} = 133\tfrac{1}{3}.$$

Therefore, the larger ends of the cones must be 16 inches in diameter and B will have a variation of speed from 75 R. P. M. to $133\frac{1}{3}$ R. P. M. The length of the cone does not affect the extreme speeds, but the longer the cones the more easily the intermediate speeds may be obtained.

Cones arranged as explained above are used to drive drying machines in bleacheries and similar places, where it is desired to vary the speed af the machine according to the weight of the cloth which is being dried. Heavy cloth requires a longer time to dry than light cloth and consequently can not be passed through the machine as rapidly. Tapered cones are also found in various cotton machines.

Stepped Cones. Stepped cones are often used in place of the tapered cones. These are really a series of pulleys side by side on a shaft, a similar series being placed on the other shaft with the large pulley on the second shaft in line with the small pulley on the first shaft. The arrangement is shown in Fig. 19. In practice the several pulleys which make up the stepped cones are cast together, both cones usually being cast from one pattern. The calculation for the diameters of the end steps are the same as for the end diameters for the cones (Fig. 17). Assuming that both cones are alike, the intermediate steps can be found as follows:—

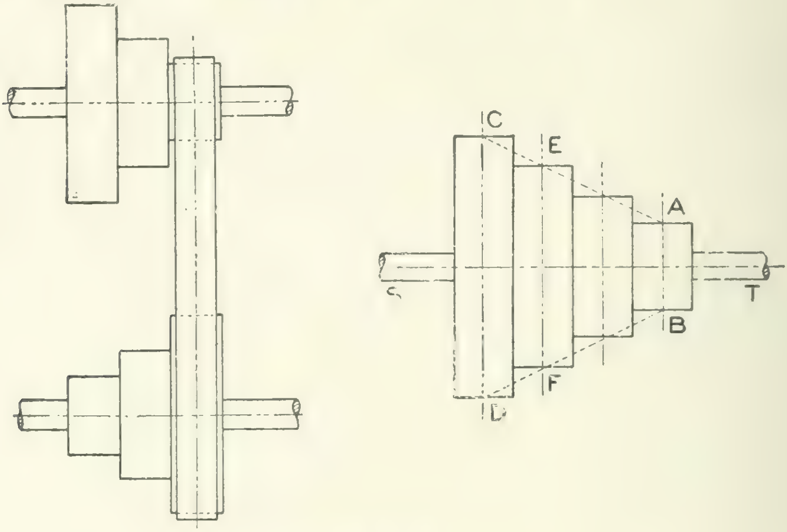


Fig. 19.

Decide how many intermediate steps are desired, then draw the center line ST, and draw the lines AB and CD perpendicular to ST and at a distance apart equal to the width of the face of one step multiplied by the whole number of steps minus one. Make CD equal in length to the diameter of the largest step and AB equal to the diameter of the smallest step. Draw AC and BD. Draw EF parallel to and at a distance from CD equal to the width of the face of one step. The distance between E and F, the points where EF intersects AC and BD, will be the diameter of the second step. Other steps may be found in the same manner. To use this method all steps must have the same width of face. It would not be accurate for an open belt, although if the distance between the shafts are large compared with the diameter of the cones, an open belt might not give trouble on cones designed in this way.

Stepped cones are very commonly used for driving lathes and other machine tools.

EXAMPLES FOR PRACTICE.

1. A shaft making 115 revolutions per minute has keyed to it a pulley 36 inches in diameter. If the pulley belted to the 36-inch pulley is 26 inches in diameter, how many revolutions will it make per minute?

Ans. 160 revolutions. (nearly.)

2. A pulley 12 inches in diameter makes 180 revolutions per minute. The other pulley connected by belt to the 12-inch pulley should make 75 revolutions. How large must it be?

Ans. 28.8 inches in diameter.

3. A motor shaft having a pulley 6 inches in diameter makes 840 revolutions. If this speed is to be reduced to 320 revolutions, what size pulley should be used?

Ans. 15¾ inches in diameter.

Disk and Roller. Fig. 20 shows a device by means of which one shaft turning always in the same direction with a constant speed may drive another shaft, which is at right angles to it, in either direction and at different speeds. A is a disk on the end of the overhanging shaft S. On the shaft T is placed a roller B free to be moved up or down on T, but on a key so that it must turn with the shaft. Some sort of a shipper must be provided to hold B in the desired position on T. When one shaft turns it drives the other by means of the friction between A and B. If shaft S is the driver, turning in the direction indicated by the arrow, it will cause T to turn in the direction indicated by the lower arrow. If it is desired to have T turn in the opposite direction, keeping the direction of S the same, B must be moved up above the center line of S as shown dotted. If OR is the distance from the center of disk A to the point where the center line of the face of B strikes

A, and LR is the radius of B, we have the following equation,—

$$\frac{\text{R. P. M. of B}}{\text{R. P. M. of A}} = \frac{\text{O R}}{\text{L R}} \qquad (6)$$

from which, knowing the speed of one, the speed of the other may be calculated. It will be seen from this equation that if OR is decreased, that is, if B is moved nearer the center line of S, the speed of B will decrease if A is the driver, or the speed of A will increase if B is the driver.

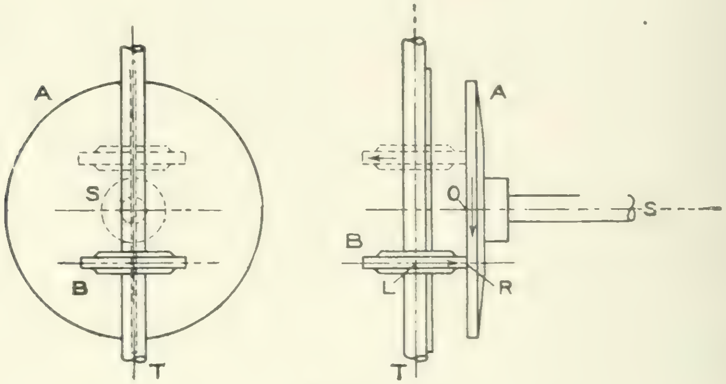


Fig. 20.

This device is used for driving drying machines where the cloth goes from another machine direct to the drying machine, and it is essential that the speed of the two should be adjusted to a nicety, in order that excessive strain may not come upon the cloth. It is also used for driving the feed mechanism on machine tools, particularly drills.

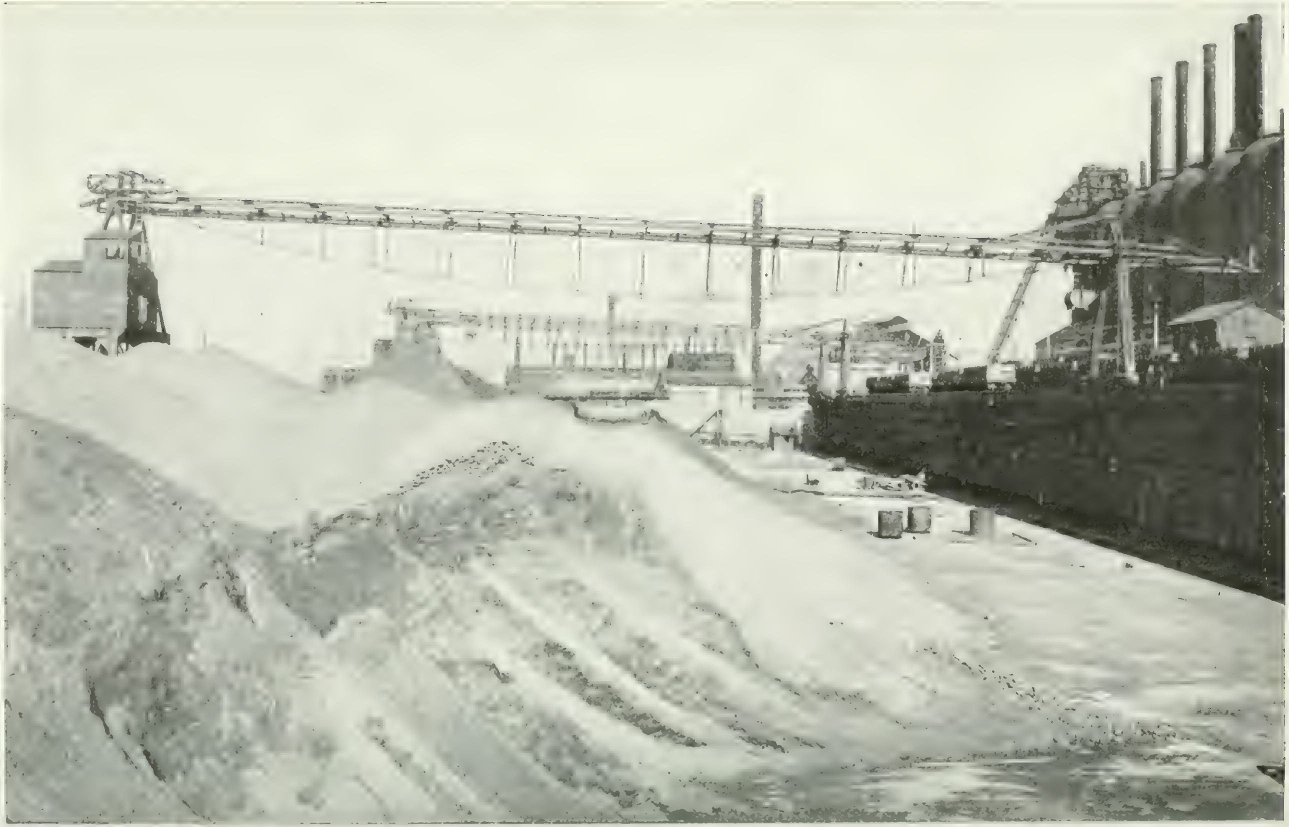
Example: Suppose the disk A makes 70 revolutions per minute and disk B 124 revolutions. If OR is 18 inches what is the diameter of B?

$$\frac{\text{R. P. M. of B}}{\text{R. P. M. of A}} = \frac{\text{O R}}{\text{L R}} \text{ or } \frac{124}{70} = \frac{18}{\text{L R}}$$

$$124 \times \text{L R} = 70 \times 18$$

$$\text{L R} = \frac{70 \times 18}{124}$$

$$= 10.16 \text{ inches (about).}$$



ORE-STORAGE AND REHANDLING PLANT.

Duquesne Furnaces, Carnegie Steel Co., Ltd.

Diameter would be $2 \times 10.16 = 20.32$ inches or 20 [illegible] inches.

EXAMPLE FOR PRACTICE.

1. Disc B, Fig. 20, is 12 inches in diameter and makes 280 revolutions per minute. If shaft S is to make 48 revolutions per minute how far from the center must the circumference of B be placed? Ans. 35 inches.

DISCONNECTING AND REVERSING MECHANISMS.

Tight and Loose Pulleys. Fig. 21 shows a very common arrangement of pulleys, whereby the shaft A may be stopped while the driving shaft B continues to run. Pulley C is keyed to shaft A, while pulley D is free to run on A. Pulley E has its face equal in width to the sum of the other two and is keyed to B. When the belt is in the position shown in full lines, D turns with E, while shaft A remains at rest. The belt is guided by a shipper and when it is desired to start A, the belt is moved into the position shown by the dotted lines.

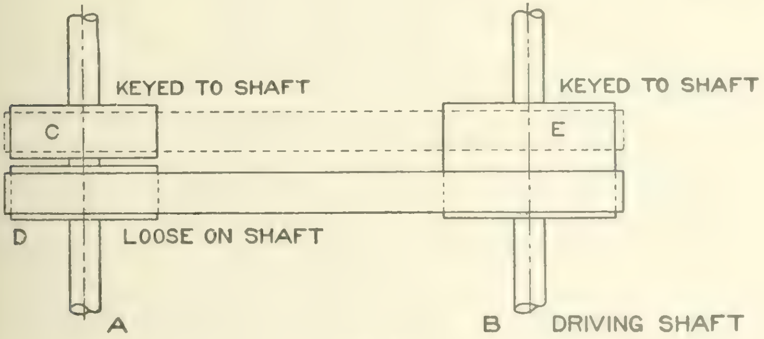


Fig. 21.

Jaw Clutch. Fig. 22 illustrates an arrangement by which the gear, or pulley, A may be attached to turn with the shaft, or disconnected so as to turn independently of the shaft. The hub of A has jaws or teeth on its end, and the sliding piece B has similar teeth, the projections on B fitting into the indentations of A. The shaft may turn freely in A while B slides on a key so that it must turn with the shaft. When B is in the position shown, the shaft and A may turn independently of each other, but when B is moved to the left so that its teeth engage with the teeth on the hub of A, it serves to clamp A to the shaft. The principle here involved is used in many different forms of clutches.

Friction Clutches. A jaw clutch such as illustrated in Fig. 22, if thrown in while the shaft or gear is turning brings a sudden shock on the parts, which is likely to cause damage, especially if the speed is high and much power is transmitted. Consequently, a clutch known as a friction clutch is often used, which, as its action depends upon the friction between two parts, will impart motion more gradually thereby avoiding the shock. Fig. 23 illustrates a simple clutch of this kind. B is a piece free to slide on a key, and held in position by a shipper. A is a pulley or gear loose on the shaft. The outer surface of B and the inner surface of A are tapered to fit each other. When B is thrown to the left it clamps A to the shaft in the same manner as the jaw clutch.

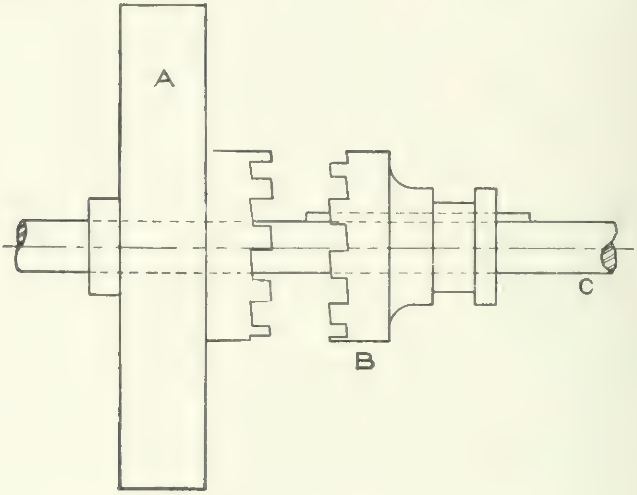


Fig. 22.

Two Clutches for Reversing. Fig. 24 shows how two clutches can be arranged so that either one may be thrown in, thus giving motion to the shaft in either direction. The clutches are similar in principle to the one shown in Fig. 23. The left-hand clutch is shown partly cross-sectioned. The piece A is attached to a shipper which when moved to the right throws in the right-hand clutch; when moved to the left throws in the left-hand clutch. If the pulley of the right-hand clutch is driven by an open belt and the pulley of the left-hand clutch by a crossed belt, the shaft will be driven

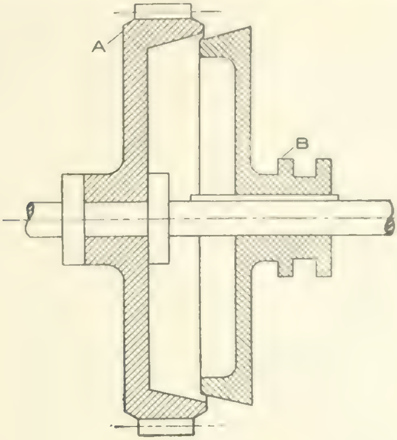


Fig. 23.

in either direction according as one or the other clutch is thrown in. When A is in the position shown neither clutch is in and the shaft is at rest.

SCREWS.

The Helix. Since all screws depend upon a curve known as

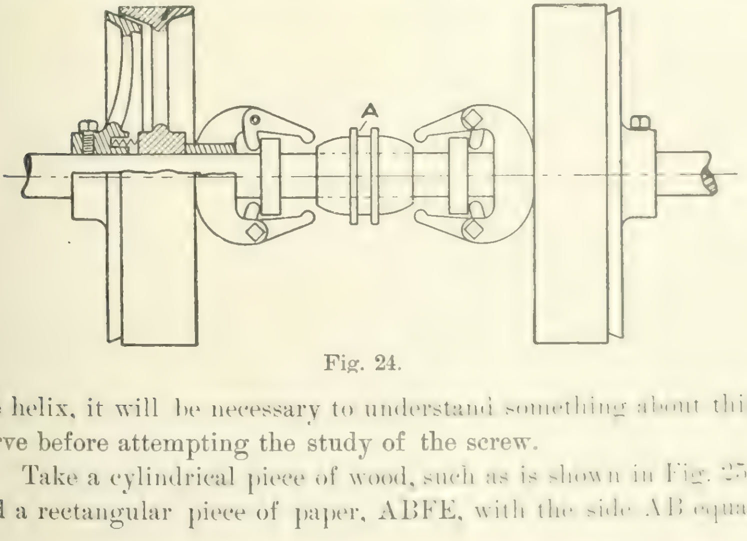


Fig. 24.

the helix, it will be necessary to understand something about this curve before attempting the study of the screw.

Take a cylindrical piece of wood, such as is shown in Fig. 25, and a rectangular piece of paper, ABFE, with the side AB equal to the circumference of the cylinder, and the side AE equal to the length of the cylinder. Now, if we lay off along AE a distance AD, and draw the line DC parallel to AB, we have the rectangle, ABCD. Now draw the diagonal, AC, of the rectangle and wrap the paper around the cylinder, keeping the side AE on an element of the cylinder; the paper will just cover the cylinder, the edge BF meeting the edge AE. The point C will coincide with D and lie on the same element of the cylinder as A and at a distance from A equal to AD. The shape which the line AC now takes is called a helix, and the distance AD is called the pitch of the helix. If

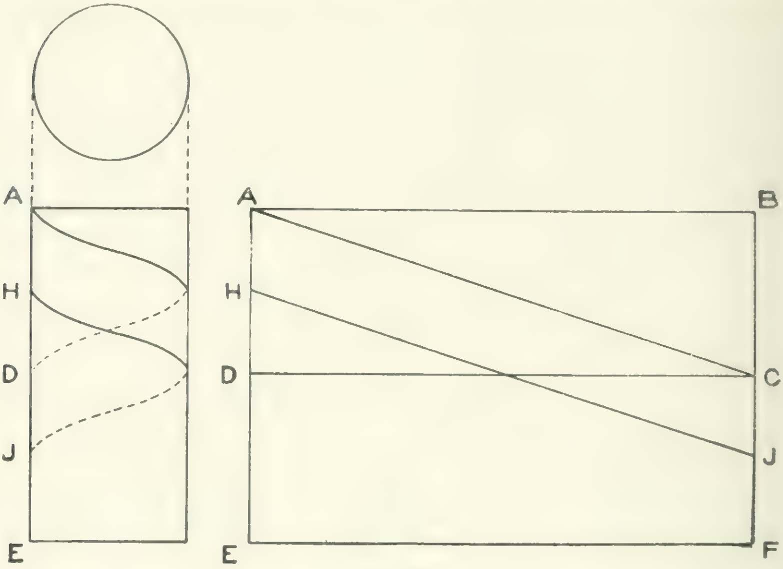


Fig. 25.

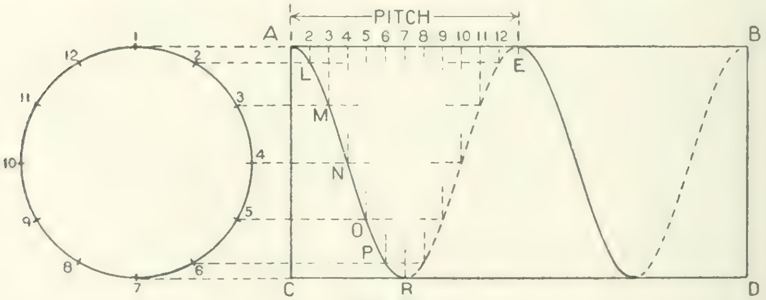


Fig. 26.

we choose another point, H, half way between A and D, and draw a line HJ parallel to AC, this line when wrapped around the cylinder will form another helix of the same pitch as the first one. The two together form what may be called a double helix. If the line AD is divided into three equal parts instead of two, and lines parallel to AC be drawn from each of the points of division, we would have on the cylinder three parallel and equidistant helices of the same pitch, or a triple helix. Fig. 26 shows a single right hand helix, Fig. 27 a single left-hand helix, Fig. 28 a double right hand helix, and Fig. 29 a triple right-hand helix.

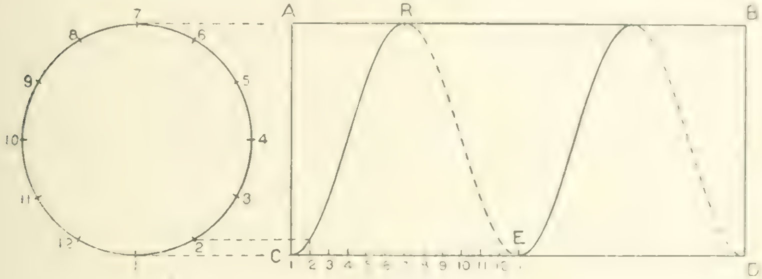


Fig. 27.

If a helical groove is cut on the surface of a cylinder, a screw thread is formed, the thread being the material which is left between the successive turns of the helical groove. A cylinder having a thread on it is called a screw, and a piece having a cylindrical hole in it, with a thread around the hole, is called a nut. The groove which is cut to form the thread may be in the form of a single, double or triple helix, and either right hand or left-hand; the thread would be described in the same terms.

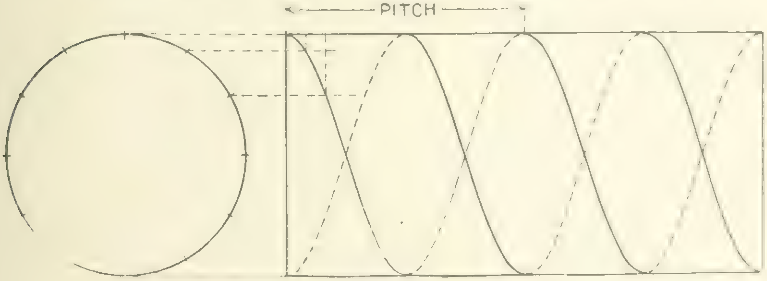


Fig. 28.

Fig. 30 shows a right-hand and a left-hand single V thread and a right-hand and a left-hand single square thread.

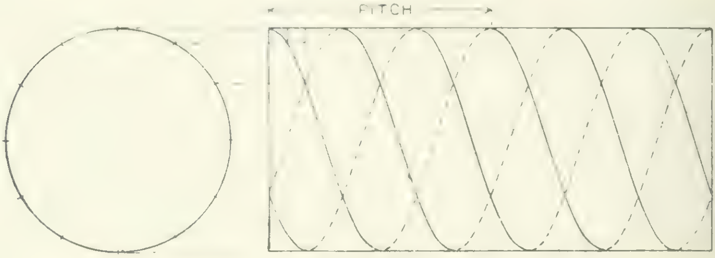
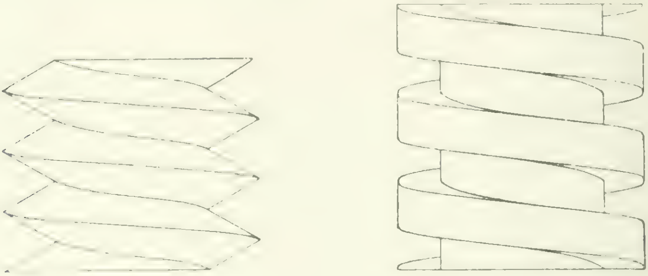
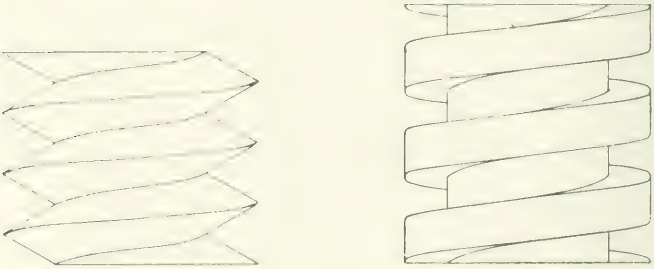


Fig. 29.

One complete turn of a screw causes it to travel through its nut a distance equal to its pitch.



LEFT HAND THREAD. LEFT-HAND THREAD.



RIGHT-HAND THREAD. RIGHT-HAND THREAD.

Fig. 30.

There are certain principles which apply and certain problems which arise, in connection with all forms of screws, and we shall now consider some of the most important of these.

Let Fig. 31 represent a jack screw. The pitch of the screw is P inches; the length of the bar from the axis of the screw to the point R, where the force is applied, is A inches. A force of F pounds is exerted at R, raising the weight W.

The following equation holds true,

$$\frac{F}{W} = \frac{\text{Distance W moves}}{\text{Distance F moves}} \qquad (7)$$

Suppose the screw to be turned once; then F will move through a distance approximately equal to the circumference of a circle whose radius is A; that is, F moves a distance $2\pi A$. In turning the screw once, W is raised a distance P. Then, substituting, in equation (7), these quantities for the distances which F and W respectively move, we get

$$(8) \quad \frac{F}{W} = \frac{P}{2\pi A} \quad \text{or}$$

$$2\pi A F = W \times P$$

$$W \times P = 2\pi A \times F$$

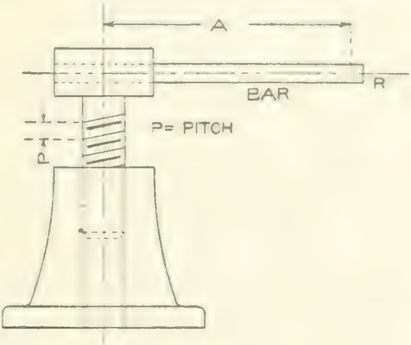


Fig. 31.

From this equation, if any three of the quantities F, W, P or A are known, the fourth may be found. P and A must both be expressed in feet or both in inches.

For example, let $P = \frac{1}{4}$ inch, A = 5 feet, F = 100 pounds. Substituting in the formule we get

$$\frac{100}{W} = \frac{.25}{2 \times 3.1416 \times 60}$$

$$.25\ W = 37699.2$$

$$W = 150{,}797 \text{ pounds (nearly).}$$

EXAMPLES FOR PRACTICE.

1. Suppose a weight of 200,000 pounds is to be raised by a jack screw. The pitch is .20 inch, and the force applied is 125 pounds. What must be the length of the bar?

Ans. 51 inches (nearly).

2. What should be the pitch of the screw of example 1 if the bar is made 6 feet long?
Ans. .28 + inches.

3. A jack screw has the following dimensions: Length of arm, $5\frac{1}{2}$ feet; pitch, .125 inch. If 200,000 pounds are to be raised what force must be applied at the end of the bar?

Ans. 60 pounds.

Combination of Screws. Fig. 32 illustrates a method by which the space moved through by the nut C may be made very small in comparison with the space moved through by a point on the circumference of the hand wheel, without using a very fine pitch on the screw. Great pressure can thus be produced at C by a small force on the wheel, without danger of stripping the thread, which might occur if the screw had a fine pitch. The upper part of the screw E has a coarse thread which acts in the nut B, this nut being rigid with the frame D. The lower part of the screw has a pitch different from the upper part and acts in the nut C. C is free to slide up or down in the frame, but is prevented from turning by the lips L.

Let $P =$ the pitch of the upper part of the screw and $p =$ the pitch of the lower part, both threads being right-hand, and P being greater than p. If the screw were attached to C by a collar instead of being threaded into it, one turn of the screw right-handed in nut B would cause the screw to advance a distance P, carrying C forward the same distance. But since by the same turn the screw has drawn nut C on to itself a distance p, the actual distance, K, which C has advanced is

$$K = P - p \tag{9}$$

If p were greater than P, K would have a minus value; that is, C would actually move up for a right-handed turn of the screw. If one of the screws is left-handed and the other right-handed, the equation would become

$$K = P + p. \tag{10}$$

Let $P = \frac{1}{4}$ inch and $p = \frac{3}{16}$ inch, and let both screws be right-handed. If the radius A of the hand wheel is 12 inches, how much pressure can be exerted at C by a force of 50 pounds, applied to the circumference of the wheel?

The same principle holds here as in the case of a simple screw; that is, the forces exerted are inversely as the distances moved through, or,

$$\frac{\text{Force at wheel}}{\text{Force at C}} = \frac{\text{Travel of C}}{\text{Travel of point on circum. of wheel}} \qquad (11)$$

so that we must first find the distance C moves for one turn of the wheel. Substituting the values of P and p in formula (9), we get

$K = \frac{1}{4} - \frac{3}{16} = \frac{1}{16}$ = distance C moves for one turn of the screw.

The distance which a point on circumference of wheel moves

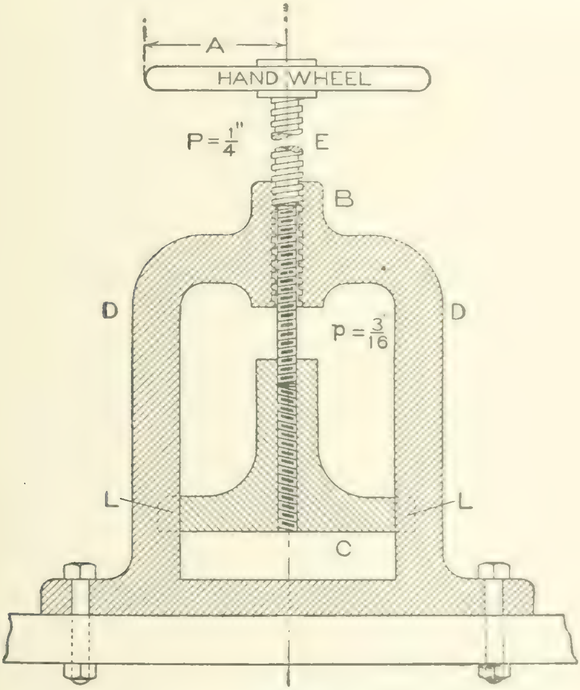


Fig. 32.

= $2 \pi A = 2 \times 3.1416 \times 12 = 75.4$ inches. Substituting these values in formula (11) we get

$$\frac{50}{\text{Force at C}} = \frac{\frac{1}{16}}{75.4}$$

Solving, we get, force at C = 60,320 pounds.

EXAMPLE FOR PRACTICE.

1. Suppose the press shown in Fig. 32 has the following dimensions: $P = \frac{1}{5}$ inch, $p = \frac{1}{6}$ inch, and the force at C is to be 78,000 pounds. What force must be applied to the circumference of the wheel if it is 14 inches in diameter?

Ans. 60 pounds (nearly).

Worm and Wheel. The mechanism known as worm and wheel consists of a wheel, as A, Fig. 33, having teeth on its circumference, and a screw or worm W, meshing with the teeth on the wheel. The axis on which the wheel is fixed is usually at right angles to the axis of the worm. If the worm is turned, the action between it and the teeth on the wheel is similar to the action between a screw and the thread in a nut, so that the wheel will turn also. If the worm is single-threaded, one turn of the worm will cause the wheel to advance one tooth, so that in order for the wheel to make one complete revolution, as many turns of the worm will be required as there are teeth in the wheel. If the worm is double-threaded, half as many turns will be required as there are teeth in the wheel; if the worm is triple-threaded, one-third as many turns will be required as there are teeth in the wheel.

Suppose the worm be single-threaded and turned by a crank whose length is R; let the worm wheel have n teeth and have on its shaft a cylinder of radius K, with a cord wound around it supporting the weight L. If a force of F pounds is applied to the crank, the same principle holds true as in the other mechanisms which we have studied, namely,

$$\frac{F}{L} = \frac{\text{Distance L moves}}{\text{Distance F moves}} \qquad (12)$$

If the worm makes one revolution, F will move through a distance $2\pi R$. The wheel makes $\frac{1}{n}$ revolutions, and consequently the cylinder to which L is attached will make $\frac{1}{n}$ revolutions. If the cylinder made a whole revolution it would raise L a distance equal to its circumference $= 2\pi K$, therefore, when it makes one revolution it will raise L a distance $\frac{2\pi K}{n}$. Substituting this value for the distance L moves, in formula (12), and substituting for distance F moves, the quantity $2\pi R$, we get

$$\frac{F}{L} = \frac{\frac{2\pi K}{n}}{2\pi R} = \frac{2\pi K}{2\pi n R}$$

Therefore,
$$\frac{F}{L} = \frac{K}{nR} \qquad (13)$$

If the worm is double-threaded, L will be raised twice as far for one turn of the worm, so that the above formula would become for a double threaded worm and wheel,

$$\frac{F}{L} = \frac{2K}{nR} \qquad (14)$$

and for a triple-threaded worm and wheel,

$$\frac{F}{L} = \frac{3K}{nR} \qquad (15)$$

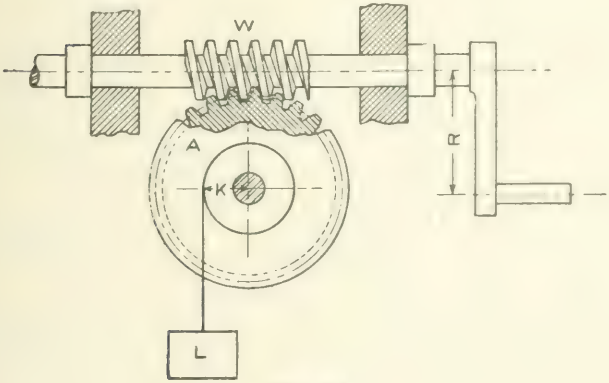


Fig. 33.

For example, a single-threaded worm makes 180 revolutions per minute and the worm wheel has 30 teeth, how many feet per minute will a weight be raised if the cylinder on the shaft of the worm wheel is 12 inches in diameter?

For each revolution of the worm wheel the worm must make 30 revolutions, hence the worm wheel makes 6 revolutions per minute. The circumference of the cylinder is 2 π R or 2 × 3.1416 × 6 = 37.699 inches and 6 × 37.699 = 226.197 inches = 18.85 feet.

EXAMPLES FOR PRACTICE.

1. A crank of 18 inches radius is attached to a worm of a single thread. The worm wheel has 48 teeth and is attached to a drum 14 inches in diameter. What weight can be raised if 80 pounds is applied to the crank?

Ans. 9874 pounds.

2. If the crank in above device is given 216 revolutions per minute how fast will the weight rise?

Ans. $16\frac{1}{2}$ feet (nearly).

3. How fast would it rise if the worm has a double thread?

Answer 33 feet.

CAMS.

A cam is a plate or cylinder having a curved outline, or a curved groove in it, which, by its rotation about a fixed axis, imparts a backward and forward motion to a piece in contact with it. The motion imparted to the follower may be at right angles to or parallel with the axis of the cam, or at some other angle.

The motions which cams are designed to give to their followers commonly belonged to one of the following kinds: uniform motion, harmonic motion, or "gravity" motion. The cam may give one kind of motion all the time or it may give different kinds of motion at different stages in its revolution.

Before studying the cams themselves, we will consider the three kinds of motions mentioned.

Uniform Motion. If a body moves through equal spaces in equal intervals of time, it is said to have uniform motion, that is, its velocity is constant.

Harmonic Motion. If a point as C, Fig. 34, travels around the circumference of a circle with uniform velocity, and another point, as E, travels across the diameter at the same time at such a velocity that it is always at the point where a perpendicular let fall from C would meet the diameter, the point E would be said to have harmonic motion. Its velocity will increase from the starting point A until it reaches the center O, and from O to D its velocity gradually decereases to zero at D.

Gravity Motion, or uniformly accelerated and retarded motion, is also a motion where the velocity gradually increases until it reaches a maximum at the middle of the path and from there gradually decreases to the end. The rate of increase and decrease, however, is different from that in harmonic motion, the velocity being increased in gravity motion, by equal amounts in equal intervals of time, the spaces traveled over in successive intervals of time being in the ratio of 1, 3, 5, 7, etc., to the middle of the path, and decreasing in the same ratio to the end.

The kind of motion which the follower is desired to have must be taken into consideration when designing a cam.

Plate Cams. Fig. 35 shows a plate cam designed to raise and lower the follower P with uniform motion. The point of P is raised from A to *c* while the cam turns right-handed through two-thirds of a revolution, and is lowered again to its original position during the remaining one-third of a revolution of the cam. In this cam the line of motion to the point of P passes through the point O, which is the center of the shaft on which the cam is fixed.

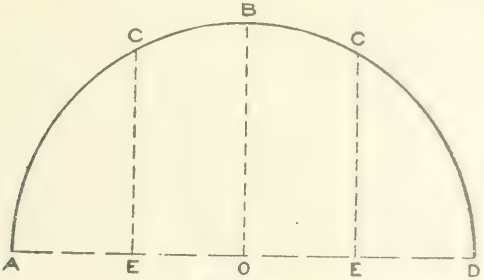


Fig. 34.

To design such a cam, draw a circle with O as a center and passing through A. Since the raising of P is to take place during two-thirds of a revolution, right-handed, find a point E on the circumference of the circle, such that the arc AHE shall be $\frac{2}{3}$ of the whole circumference, thus leaving arc ACE equal to $\frac{1}{3}$ of the circumference. Divide the arc AHE into any number of equal parts and draw the radial lines OF, OG, etc. Divide A*c* into the same number of equal parts and from the points of division 1, 2, 3, etc., thus found, swing arcs around the center O, cutting OF, OG, etc., at points *f*, *g*, etc., respectively. A smooth curve drawn through A, *f*, *g*, etc., to *m*, will give the outline of that part of the cam which raises P. The outline of the rest of the cam is found in a similar manner, by dividing arc ACE into any number of equal parts and making a new division of A*e* into the same number of equal parts. (points *d*, *c*, *b*.)

Fig. 36 shows a cam which gives the same motion to the follower as was given by the cam shown in Fig. 35, but in this case the line of motion of P, instead of passing through O, passes a distance O*a* to one side of O. The only difference in the method of designing this cam from that previously described is that instead of drawing radial lines through points A, F, G, etc., we draw lines

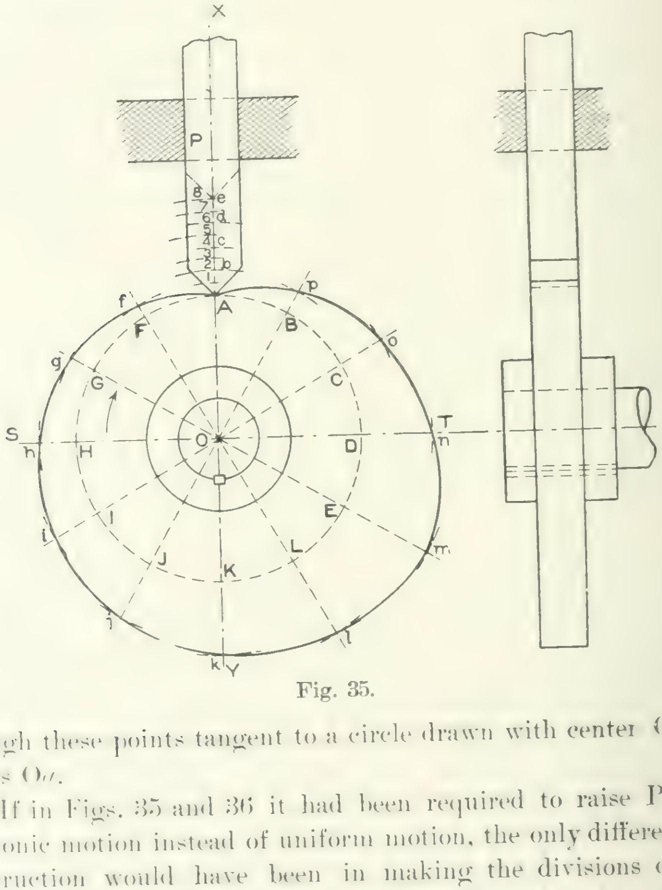


Fig. 35.

through these points tangent to a circle drawn with center O and radius O*a*.

If in Figs. 35 and 36 it had been required to raise P with harmonic motion instead of uniform motion, the only difference in construction would have been in making the divisions of A*e*. These divisions, instead of being equal, would be found as shown on a larger scale in Fig. 37. On the line A*e* as a diameter, draw a semicircle and divide this semicircle into as many equal parts as we divided the arc AHE in Figs. 35 and 36. From the points

BCD, etc. (Fig. 37), draw perpendiculars to line Ae, cutting it at points 1, 2, 3, etc. The division A – 1, 1 – 2, etc., thus found, are the divisions of Ae which would be used in finding the cam outline, in place of the equal divisions which were used for uniform motion.

Fig. 38 shows how Ae would be divided if the motion were

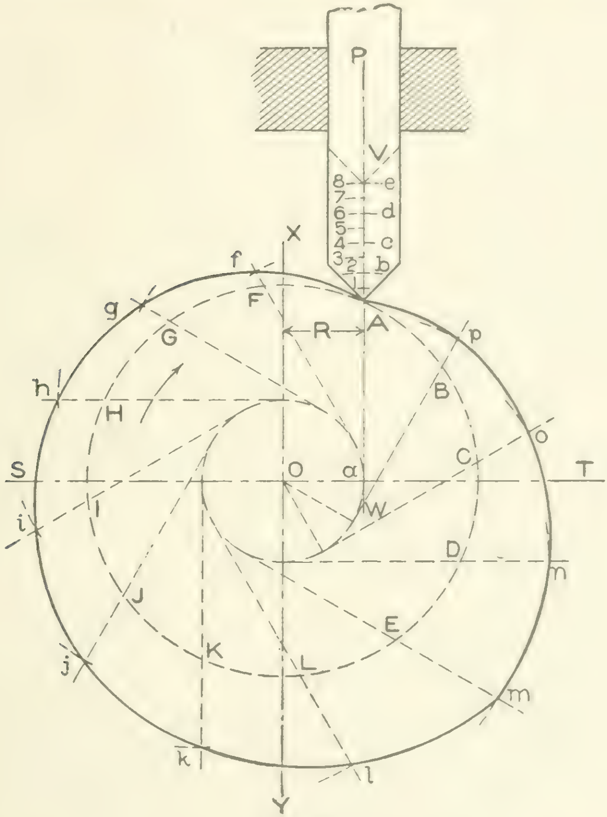


Fig. 36.

to be "Gravity." Since Ae is to be divided into as many equal parts as are AHE, in this case it will be divided into eight parts. Now if the motion which the cam is to give to piece P is to be uniformly accelerated and retarded (that is, gravity motion), Ae must be divided in such a way that the distance from 1 to 2 is three times the distance from A to 1; the distance from 2 to 3 is five times the distance from A to 1; 3 to 4 is seven times A to

1; 4 to 5 is seven times A to 1; 5 to 6 is five times A to 1; 6 to 7 is three times A to 1; and 7 to e is equal to A to 1. Therefore the whole line Ae is 1 + 3 + 5 + 7 + 7 + 5 + 3 + 1 or 32 times the distance from A to 1, or in other words, A – 1 is $\frac{1}{32}$ of the whole line Ae, and 1 – 2 is $\frac{3}{32}$ of Ae, and so on. To divide Ae so that the divisions may bear this relation to each other, draw the line AR at any convenient angle, and choosing any convenient distance as a unit, mark it off on AR thirty-two times, beginning at A. From I, the last of these dividing points, draw a line to e; next find the points B, C, D, etc., as follows: B is the first division from A, C the third from B, etc., thus getting the divisions of A1 in the ratio 1, 3, 5, 7, 7, 5, 3, 1. From the points B, C, D, etc., draw lines parallel to Ie, meeting Ae at 1, 2, 3, etc., which will be the required points of division.

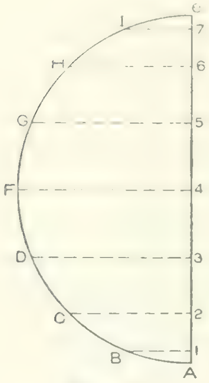


Fig. 37.

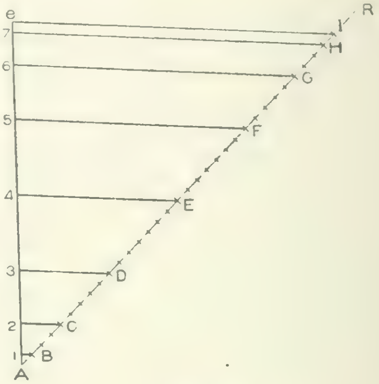


Fig. 38.

The cams which we have been considering all act on the comparatively sharp end of the piece P, and consequently much friction and rapid wearing will result if much power is transmitted. Fig. 39 shows a cam designed to act on a roller. The outline is first found for a cam to act on a piece like those in the preceding cases, with its point at the center of the roller. This curve is shown dotted in the figure. Next, with a radius equal to the radius of the roller, and with centers at any number of points around the dotted curve, draw arcs as shown. A smooth curve drawn *tangent* to these arcs will be the outline of the cam which is to act on the roller.

Cylindrical Cams. A plate cam, such as we have been considering, can be designed to give almost any kind of motion in a plane at right angles to the axis of the shaft on which the cam is located, but can not give motion parallel to the axis of the shaft. If, however, we place on the shaft a cylinder with a groove cut in it, the shape of the groove may be made such as to give to a piece inserted in it almost any motion along the shaft; or, if the depth of the groove be varied, the follower may be given a motion which shall be made up of two components, one along the shaft and one at right angles to the shaft.

Fig. 40 shows two views of a cam designed to give a backward and forward motion in a line parallel to the axis of the shaft.

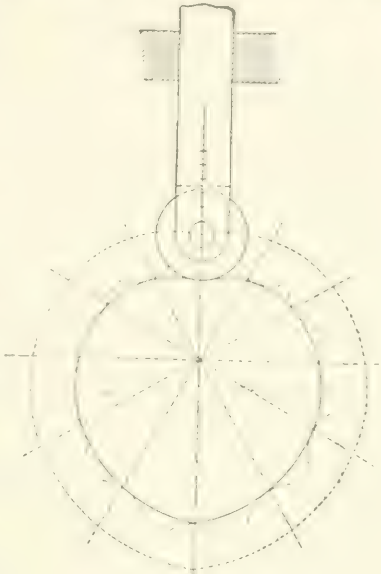


Fig. 39.

Familiar illustrations of the use of plate cams are found in the bobbin-winding mechanism on some sewing machines; on many kinds of looms, and in the valve gear on the Brown and other steam engines. Cylindrical cams are used in many places

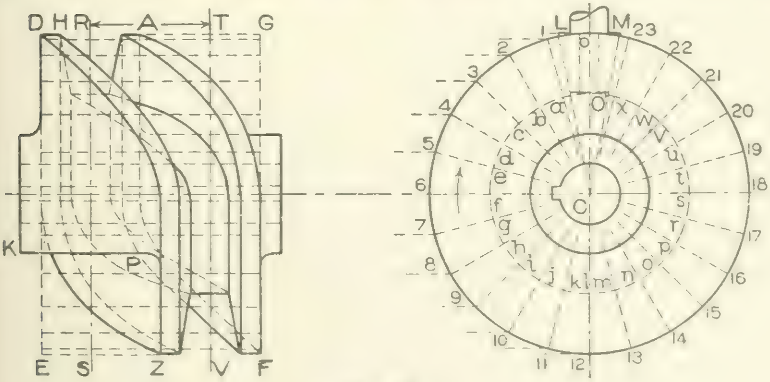


Fig. 40.

in textile work and in machine tools. One very common use is in stretchers on many forms of cloth-finishing machinery.

LEVERS.

A lever is a rigid piece supported at some point called the fulcrum, and so arranged that when force is applied at a certain point in the piece, work is done at a certain other point by reason of the pivoting action around the fulcrum. Figs. 41, 42 and 43 illustrate the three common kinds of levers the difference consisting in the relative positions of the force applied and the weight lifted, with respect to the fulcrum. In any of the three cases, if we let F = force applied, W = weight lifted, A = distance from fulcrum to weight, and B = distance from fulcrum to F, we have the following equation:

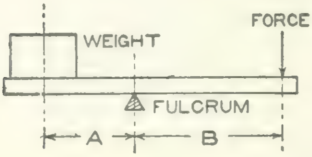


Fig. 41.

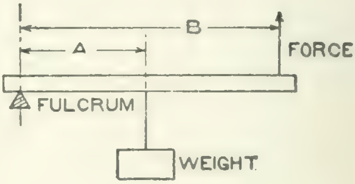


Fig. 42.

$$F \times B = A \times W \text{ or}$$

$$(16) \qquad \frac{F}{W} = \frac{A}{B}$$

from which, if any three of the quantities are known, the fourth may be found.

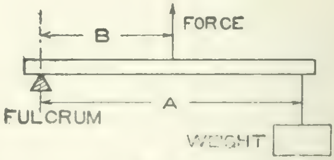


Fig. 43.

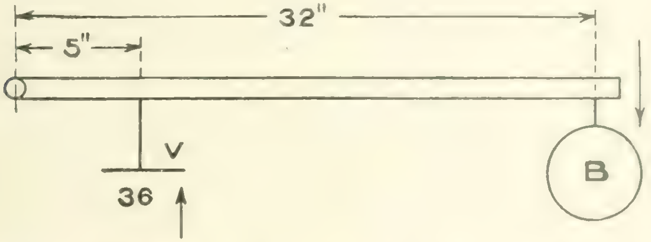
Distance A is called the *weight arm*, and distance B is called the *power arm*. The product of A times the weight is called the moment of the weight, and the product of B times the force is called the moment of the force. Another way of stating the principle expressed in equation (16) is:

Moment of force = moment of weight.

Example: Suppose a weight of 40 pounds is hung on the end of a lever. If the distance from the fulcrum to the weight is 14 inches, what power must be applied to raise the weight, the distance from the fulcrum to the power being 18 inches?

$$F \times B = A \times W$$
$$F \times 18 = 14 \times 40$$
$$F = \frac{14 \times 40}{18}$$
$$= 31.11 \text{ pounds.}$$

Another example: Let the accompanying diagram represent a safety valve. We will neglect the weight of the lever and valve. Suppose the valve V has an area of 3 square inches and the steam pressure per square inch is 36 pounds. The valve is 5 inches from the fulcrum and the weightis 32 inches from the fulcrum. What should be the weight of the ball B?



First, let us find the moment of power. The total upward pressure is $3 \times 36 = 108$, because the total steam pressure equals the pressure per square inch multiplied by the area.

The moment of power is $108 \times 5 = 540$.

The moment of weight is $32 \times B$.

$$\text{Then } 32 \times B = 540$$
$$B = \frac{540}{32}$$
$$= 17 \text{ pounds (nearly).}$$

Had we considered the weight of the valve and lever, we would have added their moments to that of the weight, because these weights increase the weight but not the power.

If in addition to the data given above, the lever weighs 10 pounds and its center of gravity is at its center, that is, 16 inches from the fulcrum. Then

$$\text{Moment of lever} = 10 \times 16 = 160.$$

The valve and valve spindle weigh 8 pounds and are 5 inches from the fulcrum, hence

$$\text{Moment of valve} = 8 \times 5 = 40.$$

$$\text{Total moment of weight} = 32 \times B + 200.$$

The moment of power is, from the previous example, 540, and we have the equation

$$32 \times B + 200 = 540$$

$$32\,B = 540 - 200.$$

$$32\,B = 340$$

$$B = \frac{340}{32} = 10.62 + \text{ pounds.}$$

Thus we see that by considering the weight of the valve and spindle and that of the lever, the ball can be reduced in weight from 17 to $10\frac{5}{8}$ pounds.

If the lever is curved as in Fig. 44, the weight arm A becomes the length of the perpendicular from the fulcrum to the line of action of the weight, and the power arm B the length of the perpendicular from the fulcrum to the line of action of the force.

LINK WORK.

Four-Bar Linkage. If we have the four rods AB, BC, CD and DA, Fig. 45, each connected to two of the others by pin and eye joints, each rod becomes what is called a link, and the whole forms a four-bar linkage. If the link AB is fixed in a position (as regards the frame of the machine) the pins at A and B become fixed centers, the links AD and BC become what are called cranks, and the link CD becomes a connecting link or connecting rod. If AD is caused to turn with a uniform angular speed about the pin of A, that is, turning through equal angles in equal periods of time, BC will be compelled to turn with some sort of motion about pin B. Whether BC shall have uniform angular motion and whether it shall make complete revolutions for complete revolutions of AD, will depend upon the relative lengths of the four links.

The center line drawn through the fixed link AB is called the line of centers, and the center line drawn through the connecting rod CD is called the line of connection. Whatever the relative lengths of the various links, the following law holds true for any position of the linkage.

$$\frac{\text{Angular velocity of crank A D}}{\text{Angular velocity of crank B C}} = \frac{\text{B H}}{\text{A K}} = \frac{\text{B E}}{\text{A E}} \qquad (17)$$

That is, if at any given instant the connecting rod be imagined removed and the cranks continue turning at the same speed at which they were moving when the connecting rod was removed, the number of turns of the cranks in a given period of time would be to each other inversely as the lengths of the perpendiculars drawn from the respective fixed centers to the line of connection, and also inversely as the distances from the fixed centers to the point where the line of connection meets the line of centers. A mathematical proof can be given for this law, but it will not be considered here.

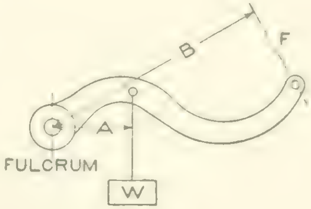


Fig. 44.

If the fixed link AB is made equal in length to the connecting rod DC, and the two cranks are equal (see Fig. 46), the connecting rod will always be parallel to the fixed link, and the perpendiculars BH and AK will always be equal, so that from equation (17) it will be evident that the speeds of the cranks are always equal. An example of a linkage of this kind is found in the parallel rod connecting the drivers of a locomotive, as shown in Fig. 47. The axles of the drivers form the fixed centers A and B, the

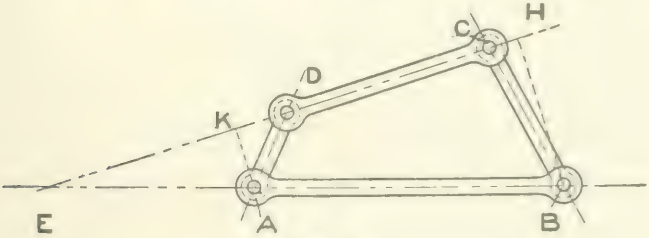


Fig. 45

frame of the locomotive forms the fixed link AB, the drivers themselves form the cranks AD and BC, and the parallel rod forms the connecting link.

Crank and Connecting Rod. In the four-bar linkage shown in Fig. 45, the pin C is compelled by crank BC to move on the arc of a circle whose center is B and radius BC. If in place of BC the fixed link is formed as shown in Fig. 48, being provided with a slot whose radius is BC and center is B, the pin C on the end of the connecting rod will have exactly the same motion that it would if guided by the crank BC. Now, if the radius of the slot is gradually increased, the slot will become nearer and nearer to being straight, so that the linkage shown in Fig. 49, where the slot is straight, may be said to be the limiting case of the linkage shown in Fig. 48. This is the linkage which we have in the crank, connecting rod, crosshead and crosshead guides of a steam engine. The crank shaft corresponds to the pin A, the frame and guides

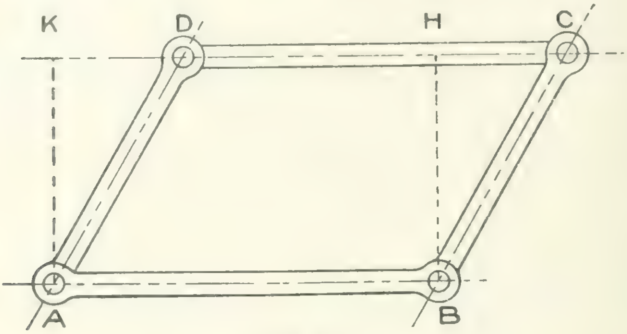


Fig. 46.

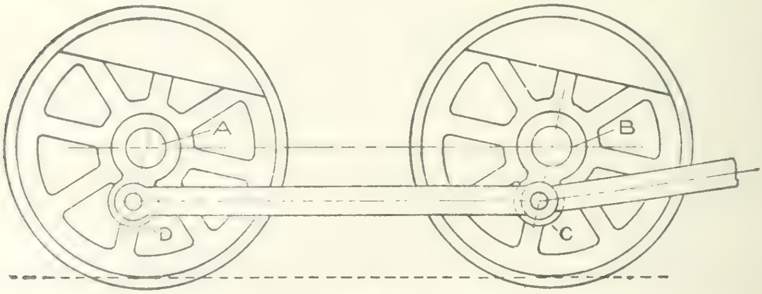


Fig. 47.

take the place of the slotted link AC. DC is the connecting rod, and AD the crank.

As there are many problems which may arise in connection with this linkage, particularly as applied to the steam engine, we will consider the most important.

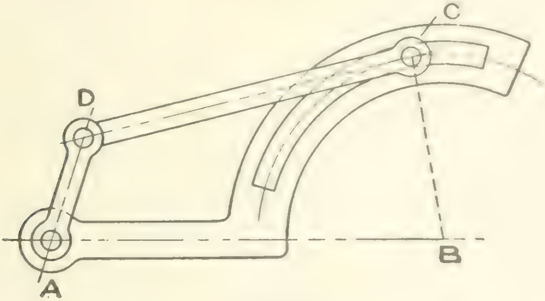


Fig. 48.

Fig. 50 shows the same linkage, the links being represented by their center lines only. AD is the crank, DC the connecting rod, C the crosshead and AC the center line through the crank shaft and the guides.

Suppose the crank has a length R and is making N revolutions per minute at a uniform speed, to find how fast the crosshead is moving at any given position of the crank.

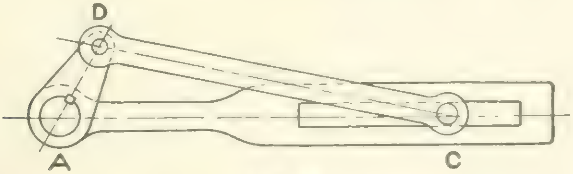


Fig. 49.

We will solve this problem partly graphically and partly by calculation. The first step is to find how fast the crank pin D is moving. For one turn of the crank, D travels through a distance equal to the circumference of a circle whose radius is R, that is, a distance of $2\pi R$. If the crank turns N times per minute the velocity of D must be $2\pi RN$. Knowing the value of R and N, for any particular case we can substite in this formula and find the actual velocity of D. Next draw the linkage at a convenient scale, in the position in which it is desired to find the velocity of C. Draw D/

perpendicular to AD and make its length represent at a convenient scale (not necessarily the same scale as was used for the links) the calculated velocity of D. This represents the actual velocity and direction of motion of the end D of the connecting rod at the instant under consideration. Now resolve the velocity D*d* into its components, along and at right angles to DC, by prolonging the line DC and drawing *d*E perpendicular to it. The component DE is the only one which has any effect on the motion of the point C. We have already learned that the motion of the two ends of a rod must have their components along the rod equal, therefore lay off from C, CF = DE. The actual motion of C is along the line CA, and, as CF is one component of the motion, the other component must be perpendicular to CF, therefore draw FH perpendicular to CF and meeting CA at H. Then CH is the velocity of point C at the same scale at which D*d* was drawn.

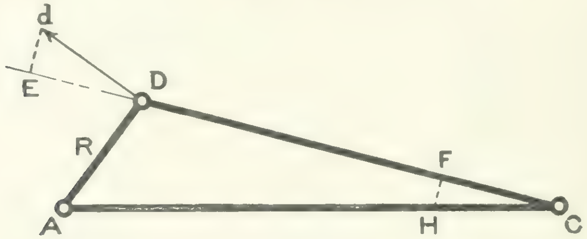


Fig. 50.

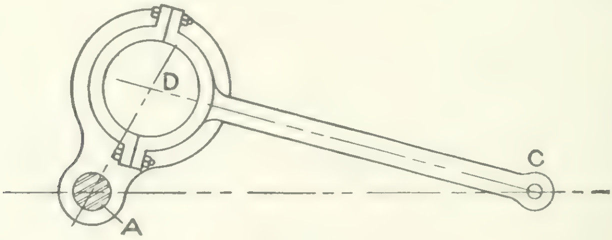


Fig. 51.

Eccentric. The eccentric and eccentric-rod linkage is in principle the same as the crank and connecting rod. To trace out the connection between the two, let us consider the crank and connecting rod shown in Fig. 51. Here the crank pin D is large and comes almost to the center of the shaft A. By increasing still further the diameter of the pin D, so that it will take in the shaft, as shown in Fig. 52, we obtain the eccentric.

Considering again the crank and connecting rod linkage: Suppose that in Fig. 53 a force F is applied at the crank pin D in a direction perpendicular to the center line AD; then the pressure which would be exerted by the slide C could be found by the same principle which we have used in previous cases, namely, the forces are inversely proportional to the velocities. Let F be the force at D, and P the pressure at C. Assume any velocity of the point D and represent this at some scale by the line Dd perpendicular to AD. Then find the velocity CH of the point C along the line AC, in the same manner as in Fig. 50. The value of CH can be measured off at the same scale at which Dd was drawn. Then

$$\frac{F}{P} = \frac{CH}{Dd} \tag{18}$$

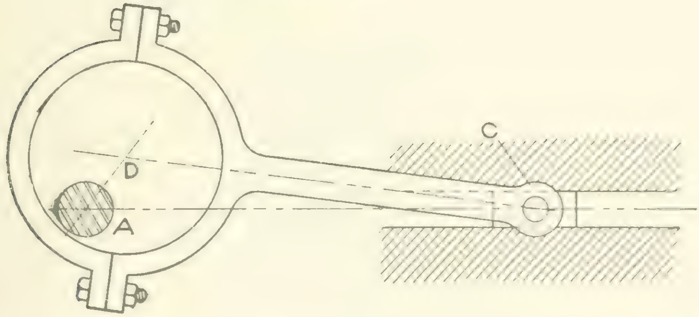


Fig. 52.

from which, if one of the quantities F or P is known, the other may be found.

If the value of CH is found for various positions of AD, keeping Dd constant, it will be seen that the nearer AD comes to coinciding with AC, the smaller CH becomes, and from equation (18) it will appear that the smaller CH is, the greater P becomes with relation to F. The above discussion will hold true if the force acts in the direction Dd or in the opposite direction.

The linkage used in this way to effect pressure at c by a force on D is known as the *toggle joint*, and is used with more or less modification in several kinds of machinery, such as punching machines, brakes on the drivers of a locomotive, etc. The force need not be applied at D, but may be applied at some other point on AD, or on some piece rigidly connected to AD but making an angle with it. This is shown in Fig. 54. Here the force is applied at E, and we can find the force at C by the same principle as before: The force at C is to force at E inversely as the velocities of C and E. The only difference is in finding the velocity of C. Assume a velocity for E, as Ee. Then

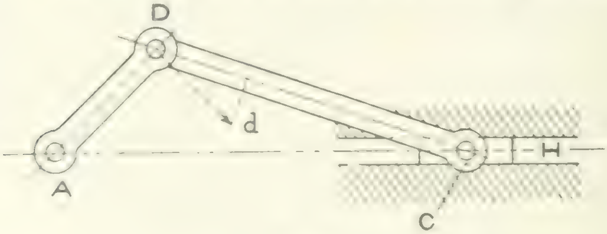


Fig. 53.

$$\frac{\text{Velocity E}}{\text{Velocity D}} = \frac{\text{A E}}{\text{A D}} \qquad (19)$$

from which the velocity of D may be found; the rest of the solution would be the same as for Fig. 53.

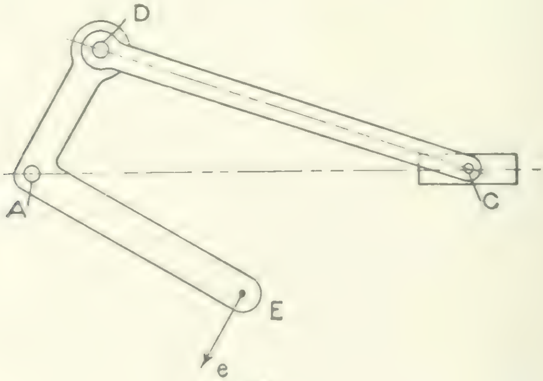


Fig. 54.

These problems may be solved by another and perhaps somewhat shorter method, but, as this would involve the resolution of forces, which have not yet been taken up in detail, we will confine ourselves to the above method.

QUICK RETURN MOTIONS.

In various kinds of machinery, particularly machine tools, it is desired to move a piece backward and forward; the forward motion being slow and the return motion more rapid. Take for example the shaper; as the tool when moving forward is cutting metal, it should go slowly and steadily, but after the cut is made it is desirable to get the tool back ready for its next stroke as quickly as possible. Many different devices are used to accomplish this result.

If in Fig. 45 we replace the connecting rod DC by a slot in the link BC, we get the linkage shown in Fig. 55. A and B are the fixed centers, AD is the driving crank (which usually turns with uniform speed), BD is the slotted crank and to some part of BD a link or some other piece is connected by means of which the tool is driven. Two distinct mechanisms are formed, depending upon the relative lengths of the links. If the proportions are such that a circle drawn around the center A, with radius AD, falls outside the center B, as shown in Fig. 56, we have what is known as a Whitworth quick return motion. Here the slotted crank makes one complete revolution for each complete revolution of AD, but its speed is not uniform. In this figure, a connecting rod PT is represented as attached to a point P on the slotted link. The other end of this connecting rod moves the tool holder T along the straight line ET. When the linkage is in the position shown, T is in its extreme right-hand position, and it will be in its

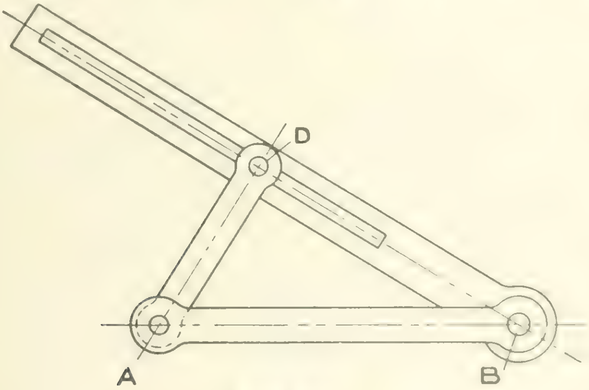


Fig. 55.

extreme left hand position when BP occupies the position BP$_1$. In turning BP through this angle (180°), AD has turned through the angle L. In returning BP to its right-hand position again, AD has to turn through the angle M only. Now, since AD turns with uniform speed and since angle M is less than angle L, T makes its stroke from left to right in less time than was required to move from right to left. The time of advance and time of return are in the ratio of angles L and M. If the length of the crank AD and the ratio of time of advance to return are known the distance AB may be found as follows:

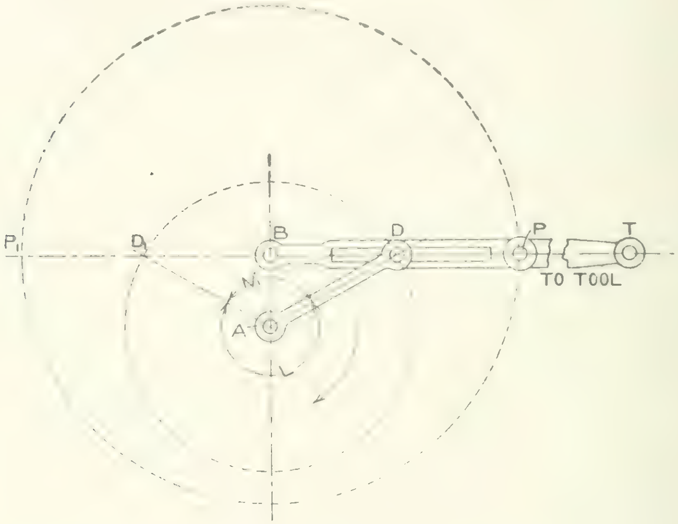


Fig. 56.

With A as a center and AD as a radius, draw a circle and divide the circumference by the points D and D$_1$ so that angle L may bear the same ratio to angle M that the time of advance bears to the time of return. Join D and D$_1$ and from A draw a line perpendicular to DD$_1$, meeting it at B, which will be the required center for the driven crank.

The distance BP governs the length of the stroke of the tool, so that by varying the position of P the length of the stroke may be varied.

If the proportions of the linkage are such that a circle drawn with A as a center and a radius AD comes inside the point B, that is, if AD is less than AB, we have what is known as a swinging block linkage. Fig. 57 shows this form of quick return motion. The piece which drives the tool is attached to the slotted link at P, which may be anywhere along the link. The linkage is shown at the extreme right of its stroke, the point D being at the point where the center line of the slot is tangent to the circle drawn with center A and radius AD, (that is, the length of the driving crank). AD_1 is the corresponding position of the crank at the other extreme of the stroke. The time of advance is to the time of return as angle L is to angle M, as in the case of the Whitworth quick return. If the ratio of advance to return and the length of AD are known, the position of B may be found by drawing the circle with center A and radius AD, and on this circle finding points D and D_1 such that the angles L and M shall have the required ratio. Then draw DB and D_1B tangent to the circle at D and D_1 respectively, meeting each other at B, which is the required center for the driven crank.

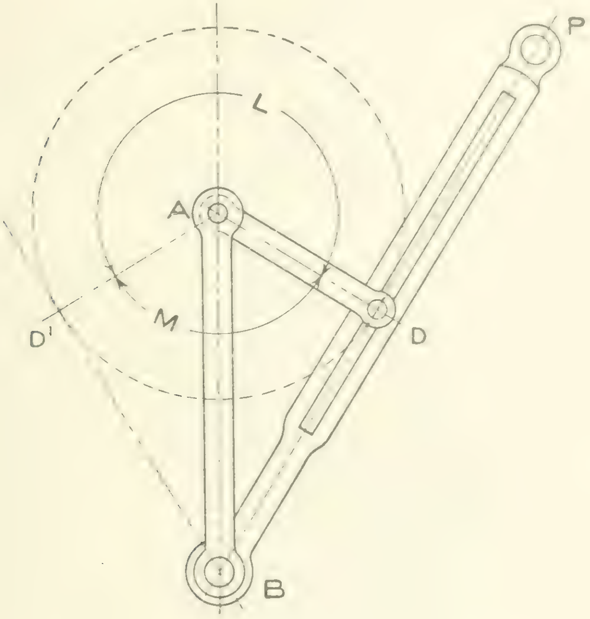


Fig. 57.

GEARING.

If shaft B, Fig. 58, has fastened to it a disc with smooth circumference, the disc being in contact at the point P with another disc on shaft A, the rotation of one shaft will cause the other to rotate, provided there is sufficient friction between the two surfaces to prevent slipping. According to the principles which we have already learned, the following equation will hold true:

$$\frac{\text{Revolutions per minute of A}}{\text{Revolutions per minute of B}} = \frac{\text{B P}}{\text{A P}}$$

In practice, the friction would not be sufficient to be relied upon, so that discs having teeth upon their circumference are used, instead of the plain discs. The discs or wheels thus formed are called gears. The teeth may have any one of several forms, and the gears may connect shafts which are parallel, intersecting at some angle, or neither parallel nor intersecting. Two gears such as shown in Fig. 59, where the shafts are parallel and the teeth on the circumference are parallel to the axis of the gear, are called **spur gears.**

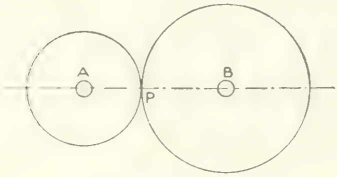


Fig. 58.

The two dot and dash circles drawn about the centers A and B and in contact at P correspond to the two discs of Fig. 58, and the gears may be said to be derived from these circles, which are called the **pitch circles**. The diameters of these circles are called the **pitch diameters** of the gears. The point P, where the two pitch circles touch each other, is called the *pitch point*. Circles drawn through the outer ends of the teeth are called the *addendum cirles*,. and circles drawn at the bottom of the teeth are called the *root circles*. These circles are indicated on the figure. That part of the tooth outlined between the pitch circle and the addendum circle, as PE, is called the **face** of the tooth, and that part between the pitch circle and the root circle, as PF, is called the **flank**. The radius of the addendum circle minus the radius of the pitch circle is called the addendum distance, or simply the *addendum*. The radius of the pitch circle minus the radius of the root circle is called the *root distance* or the *root*. The root is commonly made a little greater than the addendum, so that when two gears have their pitch circles in contact, if their teeth are of equal length they will not touch bottom, but will have some clearance. The distance from the center of one tooth to the center of the next, measured on the pitch circle, as GH, is called the **circular pitch**, or **circumferential pitch**, and is equal to the circumference of the pitch circle divided by the number of teeth.

In order to run together, two gears must have the same circular pitch. The number of teeth on two gears of the same pitch are proportional to the circumferences, and, consequently, to the diameters of their pitch circles; and as the speeds of the two shafts which are connected by a pair of gears are inversely proportional to the diameters of the pitch circles of the gears, the speeds must also be inversely proportional to the number of teeth.

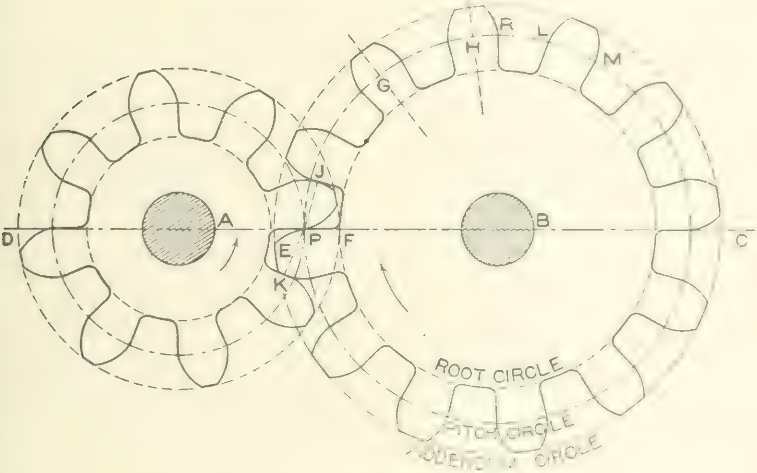
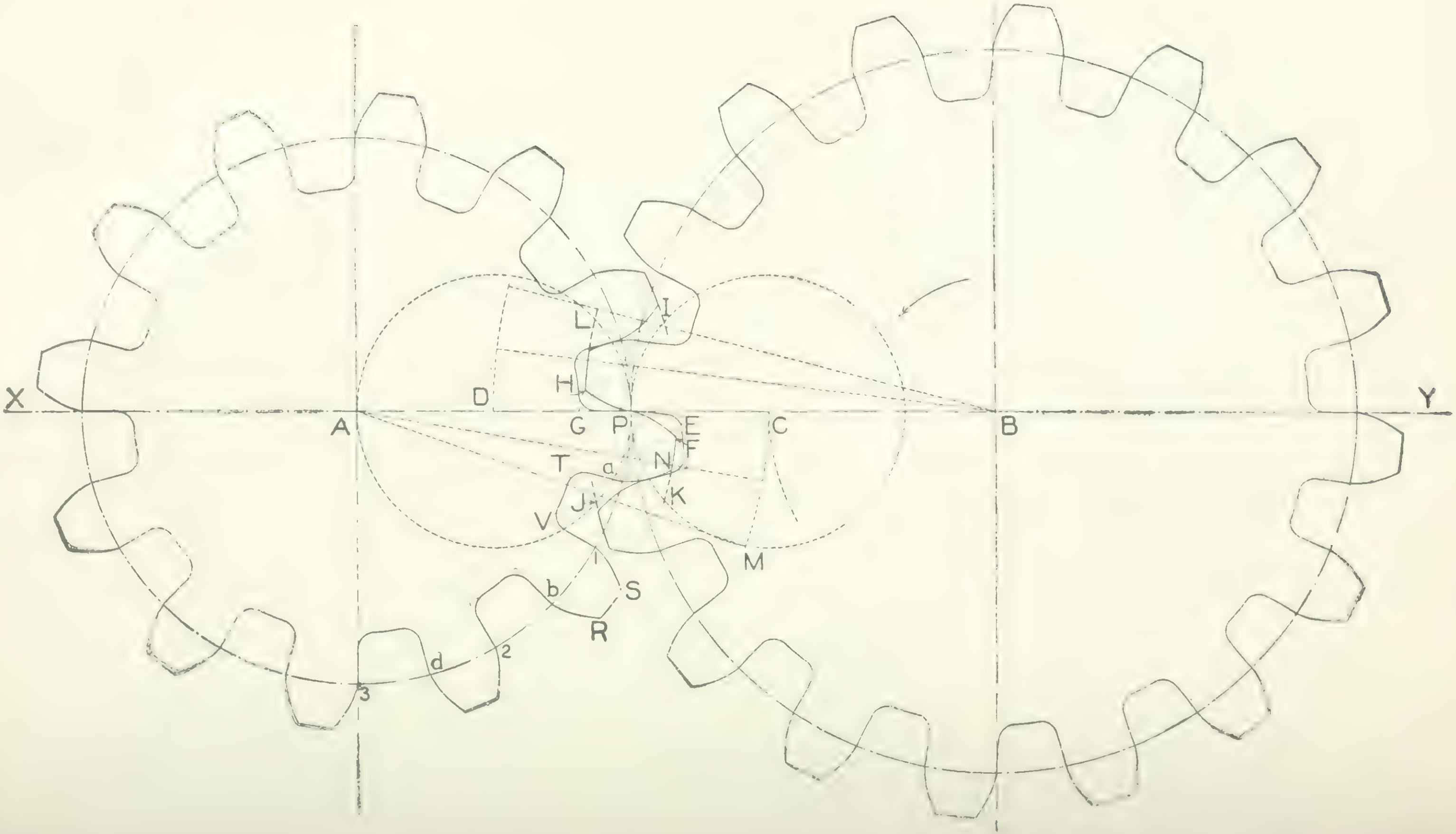


Fig. 59.

On rough gears the width of the tooth LM is made a little less than the width of the space RL, to allow for irregularity of construction. The difference in the width of the two is called the *back lash*.

Although the circular pitch is a term which is frequently used in connection with gearing, there is another kind of pitch which is often used. This is the **diametral pitch**, and is equal to the diameter of the pitch circle divided by the number of teeth, or, in other words, the amount of pitch diameter allowed for each


L
I
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b
S
R
2
d
3

tooth. The diametral pitch bears the same relation to the circular pitch that the diameter of a circle bears to its circumference; that is, the diametral pitch is equal to the circular pitch divided by π. In speaking of the pitch of a gear, instead of using the diametral pitch, which is often a fraction, it is customary to use only the denominator of the fraction. For example, if the diametral pitch is $\frac{1}{2}$ inch, it would be spoken of as a 2-pitch gear. This would be the same as saying that for every inch of pitch diameter there are two teeth.

Problems similar to the following often arise in this connection:

1. Given two gears, 4 pitch, having 12 teeth and 16 teeth respectively, to find their pitch diameters and the distance apart that their centers should be located, to run properly.

Since they are 4 pitch, their diametral pitch is $\frac{1}{4}$ inch and their pitch diameters will be their numbers of teeth multiplied by $\frac{1}{4}$, so that one would be $12 \times \frac{1}{4} = 3$ inches in diameter, and the other $16 \times \frac{1}{4} = 4$ inches in diameter. The distance on centers will be the sum of their pitch radii $= \frac{3}{2} + \frac{4}{2} = 3\frac{1}{2}$ inches.

2. Given two gears, 8 pitch, having diameters 6 and 10 inches respectively, to find the number of teeth.

The expression "8 pitch," besides meaning that the diametral pitch is $\frac{1}{8}$ inch, means that there are 8 teeth for every inch of diameter, so that one gear will have

$$8 \times 6 = 48 \text{ teeth}$$

and the other $8 \times 10 = 80$ teeth.

Referring again to Fig. 59: If gear A is driving the other gear in the direction indicated, there is a working point of contact between the teeth of the two gears at J and another at K, and as the gears turn and the teeth slide along each other, the point where a pair of teeth is in contact changes. If from the point of contact, as J, a line is drawn to the pitch P, the tooth curves should have such form that this line is normal to both curves at J, that is, PJ should be perpendicular to a line drawn tangent to both curves at J. This condition should hold, wherever the point of contact may be, in order that the gears may run smoothly.

There are two kinds of curves which are commonly used for the outlines of gear teeth, and which fulfill the above conditions.

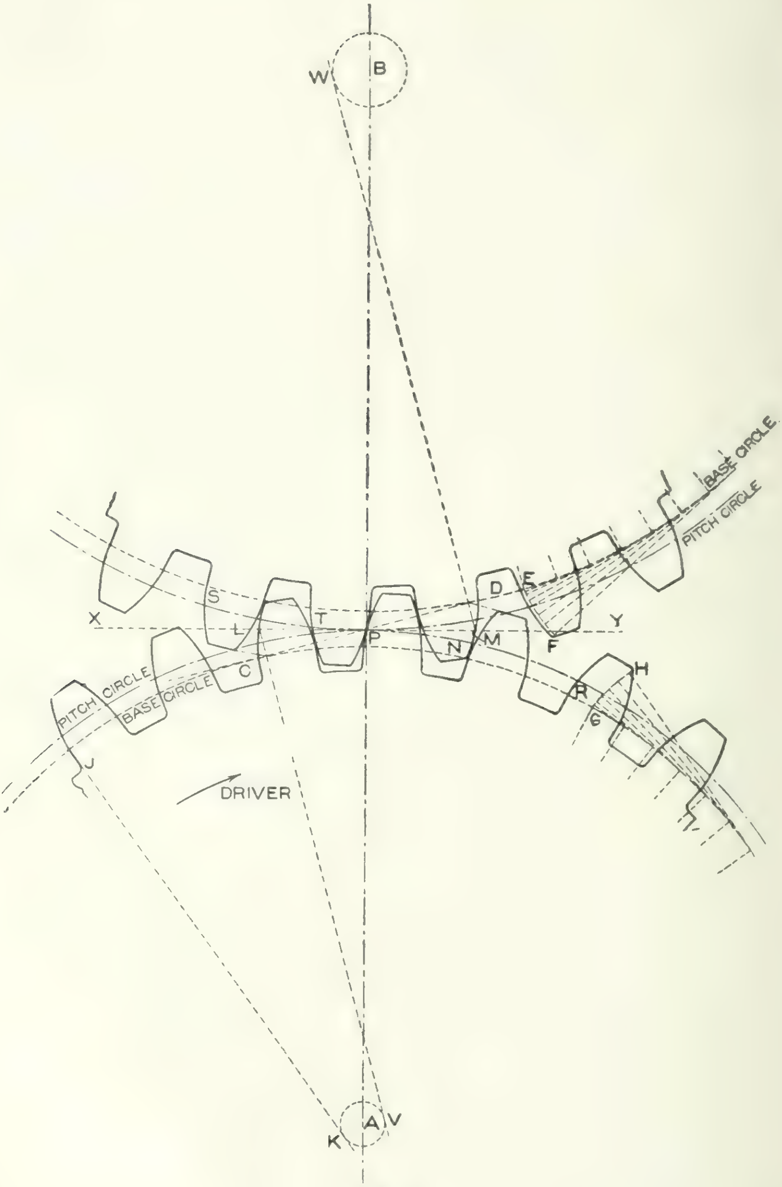

W
B
BASE CIRCLE
PITCH CIRCLE
X
S
T
L
P
D
E
N
M
F
Y
C
PITCH CIRCLE
BASE CIRCLE
H
R
G
J
DRIVER
K
A
V

Fig. 61.

These are the **involute** and the **epicycloidal** curves. Fig. 60 shows a pair of gears with epicycloidal teeth and Fig. 61 shows parts of two gears with involute teeth. The construction for getting the tooth outlines is shown in the figures, but as this properly comes under the subject of drawing, and is not essential to an understanding of gears in general, it will not be explained here.

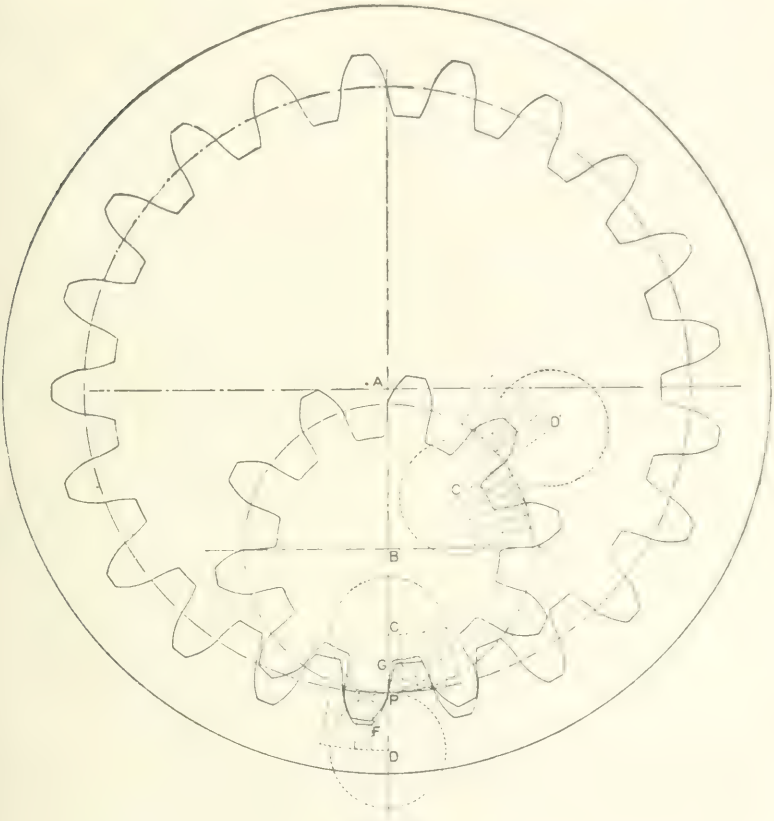


Fig. 62.

Annular Gears. An annular gear is a ring with teeth on its inside edge. Fig. 62 shows such a gear with center at A, meshing with a small spur gear called the pinion.

Rack and Pinion. A rack is a gear whose pitch line is a straight line instead of a circle. Fig. 63 shows an epicycloidal rack in gear with a pinion.

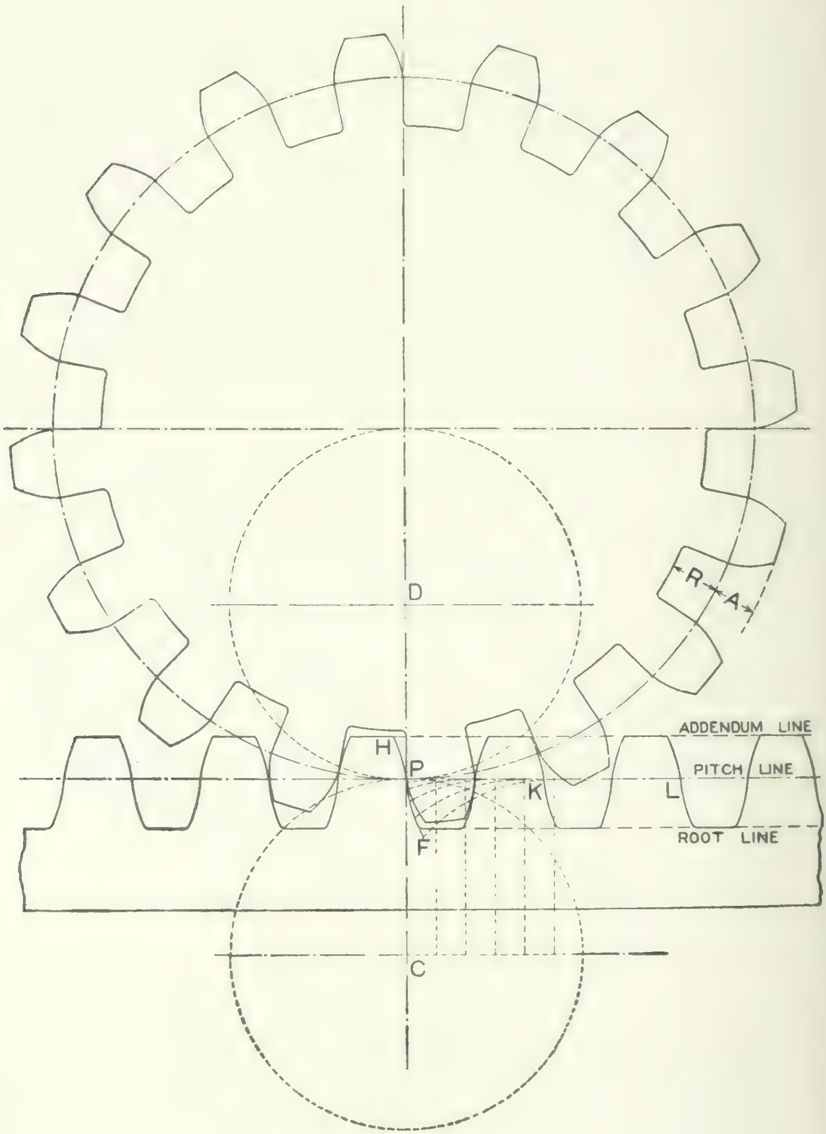


Fig. 63.

Bevel Gears. When two shafts whose axes intersect are to be connected by gears, the gears commonly used are called bevel gears. The theoretically correct pitch surface of a bevel gear is a part of the sector of a sphere, but as the designing and making of such a gear is somewhat difficult, a cone is substituted for a sphere. Fig. 64 shows a pair of bevel gears connecting two shafts which are at right angles. O is the point where the center lines of the shaft intersect, OPA and OPB are the *pitch cones* of the gears, AP and BP the pitch diameters.

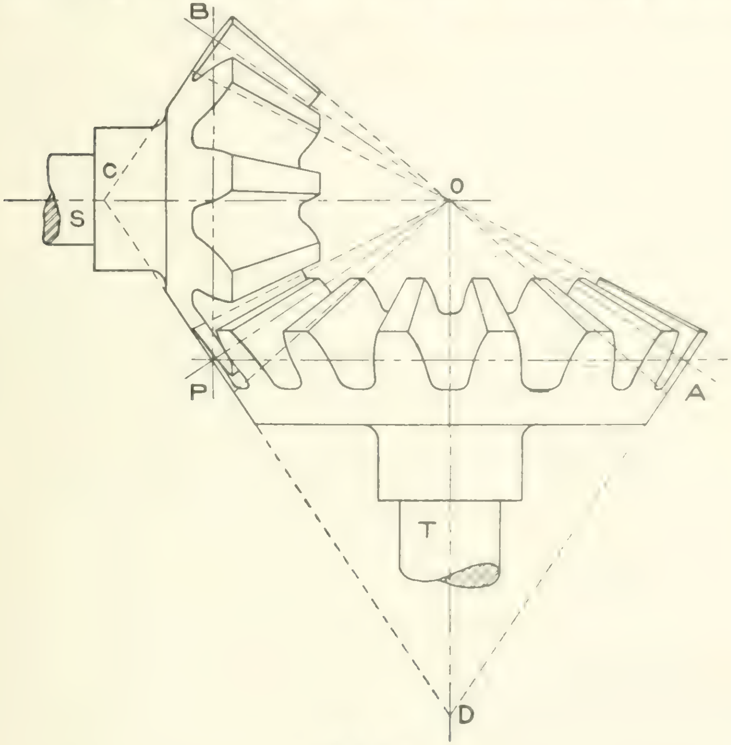


Fig. 64.

The speed of the shaft S is to the speed of the shaft T as AP is to BP. The teeth may be epicycloidal or involute, and the shafts may be at right angles or at some other angle.

Trains of Wheels. Thus far both in gearing and in pulleys and belts, we have considered only one pair of wheels, one being on the driving shaft and the other on the driven shaft. It very often happens that the connection cannot be made directly by one pair of wheels, either because the shafts are not conveniently placed with relation to each other, or because the diameters cannot be so proportioned as to give the desired speed. In such cases the connection may be made by a train of pulleys or a train of gears. Fig. 65 shows a train of pulleys, and Fig. 66 a train of gears.

In Fig. 65 shaft A drives shaft B by means of pulleys E and F. B in turn drives C by means of pulleys G and H, and C drives D by pulleys J and K.

Assume shaft A to make 100 R. P. M. and the pulleys of the following diameters:

E = 36 inches   G = 24 inches   J = 20 inches
F = 12 inches   H = 18 inches   K = 10 inches,

to find the number of revolutions of shaft D. Applying the principles which we have already learned,

$$\frac{\text{R. P. M. of B}}{\text{R. P. M. of A}} = \frac{\text{Diameter of E}}{\text{Diameter of F}} \quad \text{or}$$

$$\text{R. P. M. of B} = \text{R. P. M. of A} \times \frac{\text{diam. of E}}{\text{diam. of F}} = 100 \times \tfrac{36}{12}$$

$$\text{In like manner R. P. M. of C} = \text{R. P. M. of B} \times \tfrac{24}{18}$$
$$= 100 \times \tfrac{36}{12} \times \tfrac{24}{18},$$

$$\text{and R. P. M. of D} = \text{R. P. M. of C} \times \tfrac{20}{10}$$
$$= 100 \times \tfrac{36}{12} \times \tfrac{24}{18} \times \tfrac{20}{10}$$
$$= 800.$$

It will be noticed that pulleys E, G and J are drivers and F, H and K are driven pulleys, so that the above may be stated thus:

Revolutions of last shaft (or last wheel) = revolutions of first shaft (or first wheel) multiplied by a fraction whose numerator is the product of the diameter of all the *driving* pulleys, and whose denominator is the product of the diameters of all the *driven* pulleys. **(20)**

The same rule will apply to the train of gears in Fig. 66, if we use either the pitch diameters or the number of teeth in the respective gears where diameters are used instead of the pulley diameters.

In Fig. 65, where all the belts are open belts, all the shafts turn in the same direction; but where two shafts are connected by a pair of spur gears, the shafts turn in opposite directions, so that, in Fig. 66, the direction in which shaft D will turn with reference to the direction of A, will depend upon the number of gears in the train. The best way to determine this is to follow the train through, putting arrows, as shown, on the respective shafts.

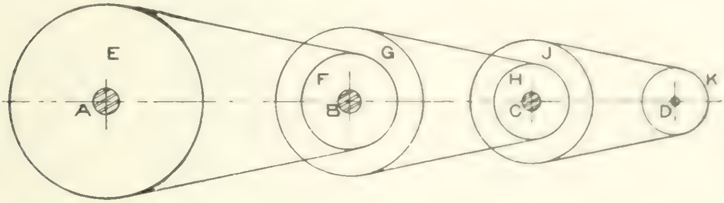


Fig. 65.

Idle Gear. In Fig. 67, gear E drives gear F, and F drives G, that is, F is both a driven and driving gear. Let E have 25 teeth, F 30 teeth, and G 50 teeth, and let shaft C make 100 R. P. M. Then from the rule given above,

$$\text{R. P. M. of A} = 100 \times \tfrac{25}{30} \times \tfrac{30}{50}.$$

In this equation the number of teeth of F (30) occurs both in

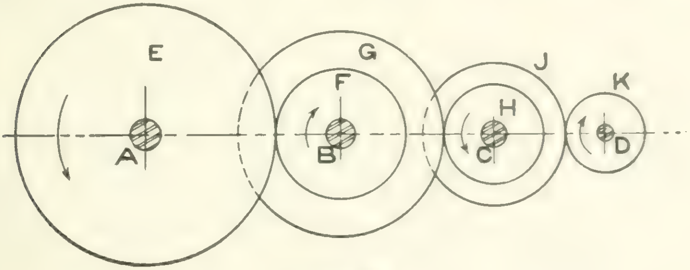


Fig. 66.

the numerator and denominator of the fraction, and will therefore cancel each other, so that the equation becomes

$$\text{R. P. M. of A} = 100 \times \tfrac{25}{50}.$$

Therefore, the speed of A depends only upon the number of teeth in E and G. Gear F is called an idle gear or idler. It should be noticed, however, that A will turn in the opposite direction from what it would if G geared directly with E.

In any train of wheels, the number of turns of the last wheel (as K in Figs. 65 and 66, or G in Fig. 67) divided by the number of turns of the first wheel, as E, is called VALUE OF THE TRAIN. Considering this statement in connection with formula (20) we have the following:—

$$\text{Value of train} = \frac{\text{Product of teeth of all drivers}}{\text{Product of teeth of all driven wheels.}} \qquad (\mathbf{21})$$

This value will be positive or negative, that is, it will have the algebraic sign + or — before it, according as the last wheel turns in the same direction as the first, or in the opposite direction.

Epicyclic Trains. In Fig. 68 the gear B is loose on the shaft H and driven by the gear E; arm A is keyed to the shaft H so that it turns when the shaft turns. Gears C and D are carried on studs on the arm. It will be evident that if B and H are caused to turn independently, the gear D will have a different number of turns on its own axis from what it would if A were fixed and D were driven directly through the train BCD.

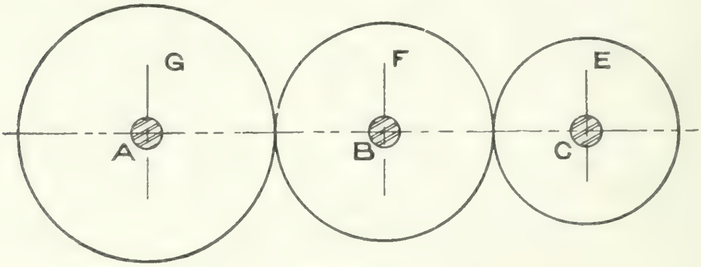


Fig. 67.

In the following formula, the value of the train is the ratio of the turns of D to the turns of B if the arm were fixed, considering B the first wheel and D the last; by the turns of B and D respectively we mean the actual number of turns they make when the arm is in motion. The formula by which the turns of A, B, or D can be found is as follows,—

$$\text{Value of train} = \frac{\text{Turns of last wheel} - \text{turns of arm}}{\text{Turns of first wheel} - \text{turns of arm}} \qquad (\mathbf{22})$$

This can be easily proved, but the proof need not be studied to understand the use of the formula. In applying this, the proper algebraic signs must be given to the value of the train, and the turns of the arm: That is, if with the arm fixed, B and D would turn in the same direction, the value of the train is considered plus, if in opposite directions, the value of the train is minus. If the arm turns in the same direction as B, the turns of the arm would be plus, but if in the opposite direction the turns of the arm would be minus, so that the formula would become,

$$\text{Value of train} = \frac{\text{Turns of last wheel} + \text{turns of arm}}{\text{Turns of first wheel} + \text{turns of arm}}$$

That is, two minus signs before the number of turns of arm would make it plus. This may be more clearly understood from a study of the following problems:

In Fig. 68 let B have 75 teeth, C 30 teeth and D 25 teeth, and let B be driven by E at a speed of 20 R. P. M. right-handed,

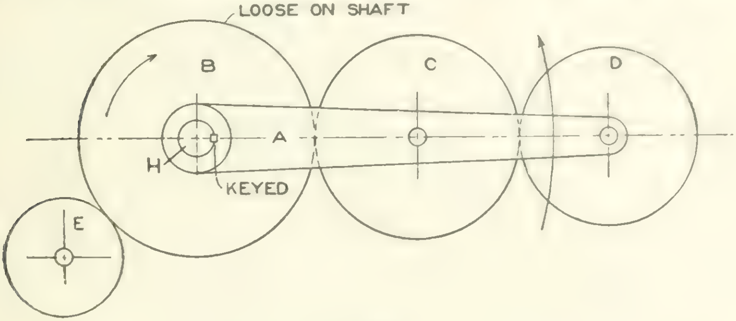


Fig. 68.

while A is driven at a speed of 2 R. P. M left-handed, to find the number of R. P. M. of D and the direction in which it will turn. We will use formula (22). The value of the train will be found from formula (21).

$$\text{Value of train} = \frac{\text{Teeth of B} \times \text{Teeth of C}}{\text{Teeth of C} \times \text{Teeth of D}}$$

$$\text{Value of train} = \tfrac{75}{30} \times \tfrac{30}{25} = 3$$

and since with the arm fixed B and D would turn in the same direction, the value of the train will be plus. Since the arm A turns in the opposite direction from B, its number of turns will have a minus sign. Then substituting the formula (22.)

$$3 = \frac{\text{R. P. M. of D} - (-2)}{20 - (-2)} = \frac{\text{R. P. M. of D} + 2}{20 + 2}$$

or

$$3 \times 22 = \text{R. P. M. of D} + 2$$

whence

$$64 = \text{R. P. M. of D}$$

In Fig. 69 the gear B, the arm A, and the annular gear D have a common axis, but are arranged to turn independently of each other about this axis. C is an idle wheel connecting B with the annular gear D and is on an axis carried by A. Let B have 30 teeth, C 45 teeth and D 120 teeth, and let B be caused to have 125 R. P. M right-handed and arm A have 75 R. P. M. left-handed, to find the number of turns and direction of motion of D. First find the value of the train if A were fixed, which would be

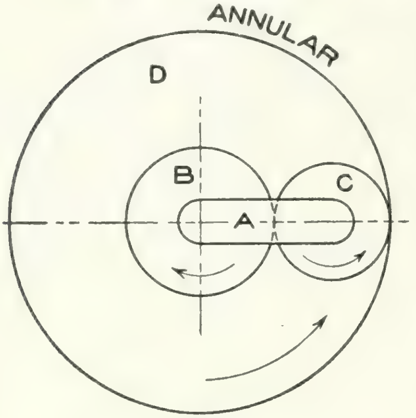


Fig. 69.

$$\frac{(30 \times 45)}{(45 \times 120)} = \frac{1}{4}$$

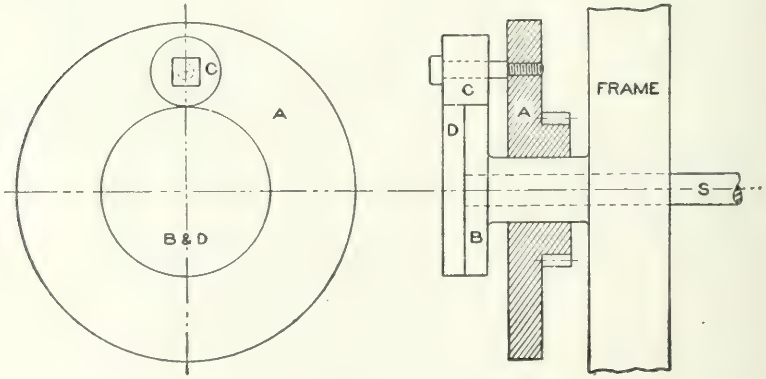


Fig. 70.

thence substituting in formula (22).

$$-\frac{1}{4} = \frac{\text{Turns of D} - (-75)}{125 - (-75)} = \frac{\text{Turns of D} + 75}{200}$$

whence turns of D = 125

that is D, makes 125 R. P. M. in the opposite direction from that in which B is turning.

In Fig. 70, gears B and D have a common axis. B is fast to the frame of a machine, D is fast to the shaft S, which drives the work on the machine. A is a disc centered on the hub which supports B, and driven by a gear (not shown) which meshes with a gear on the back of A. C is a gear carried on the stud in A. The gear B corresponds to the first wheel or driver of an epicyclic train, A to the arm, C is an idle wheel, and D is the last wheel of the train. B has one tooth more than D. Let B have 35 teeth, C 15 teeth, D 34 teeth, and let A make one turn right-handed, to find the speed of D and the direction of its motion. The value of the train, considering A fixed and B the driver, is $\frac{35}{34}$. Then formula (22)

$$\frac{35}{34} = \frac{\text{Turns of D} - 1}{0 - 1}$$

$$\text{or } -35 = 34 \text{ Turns of D} - 34$$

$$-1 = 34 \text{ Turns of D}$$

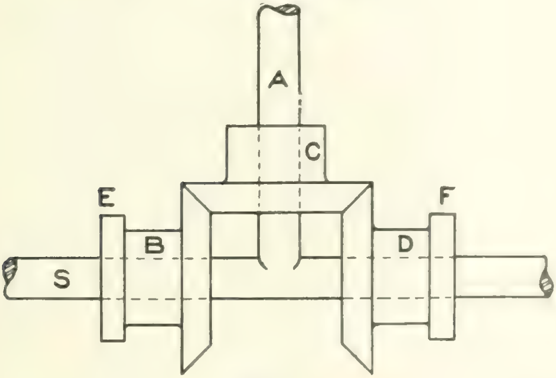


Fig. 71.

or Turns of D = $-\frac{1}{34}$. That is, for one turn of A right-handed, with B fixed, D makes $\frac{1}{34}$ of a turn left-handed.

In Fig. 71 is shown an epicyclic train of bevel gears. The shaft S carries the shaft A either welded to it or clamped on it in some way. Loose on S are the bevel gears B and D, held in place by collars (not shown) and loose on A is the bevel C, gearing with each of the others. Fast to B is the spur gear E, which is driven from some source of power not shown. S is driven from some external source of power, thus causing the arm A to swing around. Let all of the bevels have the same number of teeth, and let B be driven at a speed of 50 R. P. M. right-handed, and S at a speed of 25 R. P. M. right-handed, to find the speed and direction of D. Formula (22) applies here as in other cases which we have considered.

$$\text{The value of the train} = -1$$

$$\text{Then } -1 = \frac{\text{Turns of D} - 25}{50 - 25}$$

$$-25 = \text{Turns of D} - 25.$$

$$\text{Therefore, Turns of D} = 0.$$

Again let B turn 50 R. P. M. right-handed, to find the direction and number of turns of A in order that D shall turn 25 R. P. M. left-handed.

$$-1 = \frac{-25 - \text{Turns of A}}{50 - \text{Turns of A}}$$

$$-50 + \text{Turns of A} = -25 - \text{Turns of A}.$$

$$\text{Therefore, Turns of A} = 12\tfrac{1}{2} \text{ right-handed.}$$

REVIEW QUESTIONS.

PRACTICAL TEST QUESTIONS.

In the foregoing sections of this Cyclopedia numerous illustrative examples are worked out in detail in order to show the application of the various methods and principles. Accompanying these are examples for practice which will aid the reader in fixing the principles in mind.

In the following pages are given a large number of test questions and problems which afford a valuable means of testing the reader's knowledge of the subjects treated. They will be found excellent practice for those preparing for College, Civil Service, or Engineer's License. In some cases numerical answers are given as a further aid in this work.

REVIEW QUESTIONS

ON THE SUBJECT OF

PATTERN MAKING.

PART I.

1. What are some of the causes of warping in lumber?

2*a*. When is metal used for patterns?

2*b*. Why is metal better than wood?

3. Why should plenty of oil be used on an oil-stone?

4. Explain with sketch the method used in casting a small hollow cylinder.

5. For what parts of the pattern must the shrinkage rule be used?

6. Is the draft always the same on all parts of a pattern?

7. What is the usual allowance for finish on small castings?

8. When must a greater amount be allowed?

9. Under what conditions will a seasoned board warp?

10. What wood is most commonly used in pattern making?

11. Explain the difference in the manner in which saws cut when ripping and when crosscutting.

12. In what direction should the grindstone revolve when grinding scraping tools or other tools having a short bevel?

13. When is dry parting sand used?

14. Should a shrinkage rule be used when making a core box?

15. Why must the pattern maker know something of Mechanical Drawing?

16. When it is necessary to use a wide piece for a pattern, how may the tendency to warp be counteracted? Make sketch

17. Explain the use of the cap-iron of a plane.

18. What portion of the skew chisel does the cutting?

19. What is meant by shrinkage in pattern making?

20. How are the exact proportions of shrinkage obtained for different parts of the pattern?

21*a*. What is the usual proportion of draft to each twelve inches of surface on the face of a pattern for a cast-iron pulley?

21*b*. What proportions on the inside of the rim and on the hub?

22. When is it necessary to use mahogany, cherry, or maple for patterns?

23. What is lead in a plane-iron, and what determines the amount?

24. Explain the use of a flask in moulding, and describe the two principal parts.

25. What allowance must be made on the pattern for shrinkage when the casting is made of iron?

26. Explain what is meant by *draft* in pattern making?

27. How should lumber for patterns be seasoned?

28. When a large piece is to be used for turning, should it be cut from a plank of the required thickness or glued up out of thinner stock? Give reasons for answers.

29. Explain the methods of grinding the brad-awl and the advantages of each method.

30. Explain the use of core prints.

31. What is the allowance for shrinkage of brass?

32. What are the usual allowances for draft?

33. What is meant by *finish* in pattern making?

34. When gluing up pattern stock, how is the pressure necessary to bring the glued surfaces in close contact usually obtained?

REVIEW QUESTIONS

ON THE SUBJECT OF

PATTERN MAKING.

PART II

1. What are rapping plates?

2. Describe the process of gluing two thin pieces having large surfaces.

3. How is end wood treated if it is to be glued to other wood?

4. Explain why the upper core print sometimes has excessive draft, while the lower has but little draft.

5. What are fillets, and where are they used on patterns?

6. Give the dimensions for the arms of a six-arm pulley 40 inches in diameter and 12-inch face: (a) Width and thickness at hub. (b) Width and thickness at rim.

7. The pulley mentioned in Question 6 is to be fitted to a shaft $2\frac{9}{16}$ inches in diameter. (a) What should be the diameter of the hub? (b) What should be the length of hub?

8. What is a follow board, and when is its use necessary?

9. A pair of tight and loose pulleys 12 inches in diameter and $6\frac{1}{4}$ inches width of face, are to be fitted to a $1\frac{11}{16}$ inch shaft. (a) Give diameter of the hub. (b) Give length of hub.

10. What must be the outside diameter of the original wooden pattern for the rim of a pulley with six arms, the diameter of the finished pulley to be 30 inches and the width of face 9 inches?

11. (a) In the above pulley what should be the width and thickness of the arms at the rim? (b) What should be the width and thickness of the arms at the hub?

12. What are *core prints* and when do they form a necessary part of a pattern?

13. How are the two parts of a parted pattern held together for turning? Give two methods.

14. What are the proportions of alcohol and shellac gum for pattern maker's shellac varnish?

15. Is it always necessary to make a pattern in two parts?

16. How is colored shellac varnish made? (a) How is black made? (b) How red?

17. Give a sketch, including all dimensions, of the pattern for a plain brass cylinder which is to be finished "all over," the finished sizes being 6 inches long, 4 inches outside diameter, and $3\frac{1}{2}$ inches inside diameter. All shrinkage rule measurements, allow $\frac{3}{32}$ inch for finish.

18. What is a core box, and for what purpose is it used?

19. What is used to give a hard, smooth surface to a completed pattern?

20. What color should be used for the inside of a core box?

21. How can the pattern for a small hollow cylinder be moulded if made in one piece, (not parted)?

22. Why are core prints shellaced in a different color from the body of the pattern?

23. What are *dowel pins*, and why are they used in a parted pattern?

24. How long a time should each coat of shellac have for drying before another coat is applied?

25. Give sketch showing shape and dimensions of core box for pattern mentioned in Question 17.

26. It is required to make the pattern for a five-arm 15-inch hand-wheel, the rim and hub of which are to be turned and finished. The finished diameter of the round rim is to be $1\frac{5}{8}$ inches, and of hub $2\frac{1}{4}$ inches. Allowing $\frac{1}{16}$ inch for finish, give all dimensions for the wooden pattern, including width and thickness of arms at the rim and at the hub.

27. Give a sketch and all dimensions (shrinkage rule measurements) of the pattern for a cast-iron cylinder having a projecting flange, on each end (see Fig. 149), the cylinder to be bored out and finished all over, the finished sizes being as follows: Length 8 inches, diameter of flanges $5\frac{1}{2}$ inches, thickness of flanges $\frac{3}{8}$ inch the diameter of the body of the cylinder outside 4 inches, and inside $3\frac{1}{4}$ inches, allowing $\frac{1}{8}$ inch for finish.

28. Can the above pattern be moulded without being parted?

REVIEW QUESTIONS

ON THE SUBJECT OF

FOUNDRY WORK

PART I

1. Why is facing used on a mold?

2. What is the practical way to test the temper of molding sand?

3. What are chaplets?

4. What three forms of gases must be carried off by venting?

5. What is a skimming gate?

6. What are the properties of a good molding sand?

7. When making a large core what provision is made for handling it after baking?

8. How should a deep mold of heavy section be gated?

9. How are molds for pulleys usually gated?

10. What are risers?

11. What is the effect on the casting of ramming the mold too hard?

12. Name two means used to support the sand in the cope of a mold?

13. What are the common forms of chaplets?

14. How are the sides of deep molds vented when a flask is used?

15. What is the upward pressure on a cope where the exposed surface is 2 feet square and the depth 10 inches?

16. Why is blacking used on a core?

17. How are molds secured before pouring?

18. What are gaggers?

19. What precautions are taken in venting the sides and bottom of work which is bedded in the floor?

20. Name three important objects sought in venting a mold.

21. What size of runner is good on bench work?

22. What is the object in using a sand match?

23. Where are gaggers most commonly used?

24. What precaution is taken with sand coming next the pattern?

25. What is the danger resulting from too soft ramming?

26. How are bench molds vented?

27. How does a skimming gate act in keeping impurities out of a mold?

28. How should thin work be gated?

29. What is the object in feeding castings?

30. Why is hay rope used on loam or barrel cores.

31. How are small patterns arranged when quantities of the same piece must be put up by hand?

32. What operations are done on the three ordinary classes of molding machines?

33. How are molding machine patterns drawn?

34. How is the vent taken from the ends of long cores?

35. How are the cores for pockets or deep recesses in a casting supported in a mold?

36. Give two methods of coring holes through a casting at a level below the joint line.

37. How are cores hung in the cope?

38. How may a warped core plate be used for baking a flat core?

39. What are the advantages of using a machine to make stock cores?

40. How are irregular shaped cores like port cores baked?

REVIEW QUESTIONS

ON THE SUBJECT OF

FOUNDRY WORK

PART II

---

1. What is meant by the sand bottom of a cupola? How is it formed?

2. How many thicknesses of fire brick is usually placed inside of the shell of a cupola?

3. In the design of a cupola, what bearing should the class of work to be poured have on the height at which the tuyères should be placed above the bed?

4. What are some of the precautions necessary in pouring a mold in order to obtain the best results?

5. Describe the operations in making a simple loam mold.

6. Having 35 per cent of a mixture settled upon, with a silicon content of 2.40 per cent, in what proportions could No. 1 and No. 3 irons be added, with silicon 2.65 - 1.75 per cent respectively, so that the castings should contain 2.00 per cent silicon? Deduct 20 per cent silicon for loss in cupola.

7. State the successive steps necessary in operating a cupola furnace.

8. How should the bed charge for a new cupola be determined?

9. What regulates the amount of fuel to be put between the charges of iron in a cupola?

10. What is the difference between the shrinkage of steel castings and that of iron?

11. What are some of the methods used to produce sound steel castings?

12. How is steel poured? What precautions are taken to prevent a mold for steel being "cut" by the rush of the metal?

13. What precautions are taken to prevent fracture at interior corners on steel castings?

14. How does the riser on a steel casting differ from one for iron?

15. What kinds of flasks are generally used for steel molds? Why?

16. What process are the larger steel castings put through to relieve internal shrinkage strains?

17. What are some of the properties of brass molding sand?

18. In what order are the metals for bronze melted?

19. What care must be used in melting and mixing brass?

20. What is the highest percentage of tin that may be mixed with copper and form a serviceable alloy?

21. What are the usual proportions of copper and zinc in yellow brass?

22. How is a common brass furnace constructed?

23. Why must copper alloys be melted without access of oxygen?

24. What is the best modern method of heating and ventilating a foundry?

25. What is the basis of Keeps tests; and what size bar is used for them?

26. What is the size of the test bar or "Arbitration Bar" so called, recommended by the American Foundrymens' Association; and how is it poured?

27. What is the advantage of overhead traveling cranes over jib cranes?

28. Where should the blower be placed in relation to the cupola?

29. What is the advantage of having the coke and iron storage on a level with the charging platform of the cupola?

30. How are floors for light work supplied with iron when at a distance from the cupola?

31. Where should the sand mixers be placed relative to the sand storage bins?

32. What points should be considered in locating the foreman's office?

33. In an 8 ton heat the first metal came down at 2:30 o'clock, the bottom was dropped at 4:15 o'clock. What was the rate of melting for that heat? (Divide tons by time in hours).

REVIEW QUESTIONS

ON THE SUBJECT OF

MECHANISM.

1. An engine makes 280 revolutions per minute. If the stroke is 16 inches, what is the linear velocity of the crank pin in feet per second?

2. The pitch of a jack screw is $\frac{1}{4}$ inch. The length of the bar is 4 feet. What weight can be lifted if the force applied at the end of the bar is 148 pounds?

3. A worm of double thread meshes with a worm wheel having 64 teeth. How many revolutions per minute must the worm have to turn the wheel 2 times per minute? .

4. A lever safety valve has a lever 30 inches long. The weight hung on the end weighs 24 pounds. If the valve is $4\frac{1}{2}$ inches from the fulcrum and has an area of $3\frac{1}{4}$ square inches, at what pressure per square inch will it blow off?

Neglect weight of valve, spindle and lever.

5. Define circular pitch. Diametral pitch.

6. If a gear has 20 teeth and it is 6 pitch, how far will the rack move in $2\frac{1}{2}$ revolutions of the gear?

7. Find the piston speed in feet per minute of an engine making 5.4 revolutions per second, the stroke being 18 inches.

8. Two gears mesh with each other. They are 8 pitch. If they have 40 teeth and 68 teeth, respectively, what are the diameters and how far apart should the centers of the shafts be placed?

9. The pitch circle of an annular gear is 36 inches in diameter. The spur gear meshing with it is 8 pitch and has 24 teeth. How many revolutions must the spur gear make to turn the annular gear 13 times per minute?

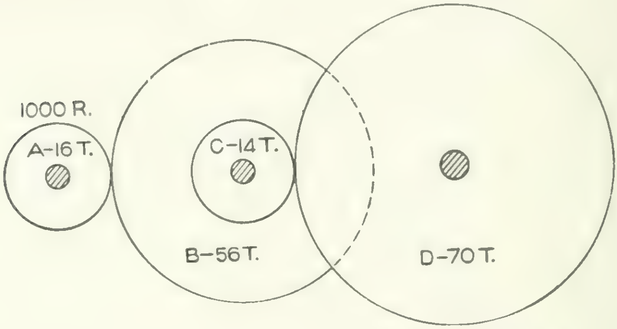
10. A lever is 26 inches long. A weight of 20 pounds is hung on one end. The distance of this weight from the fulcrum is 11 inches. What power will be necessary to raise the weight if the distance from the fulcrum to the power is 15 inches?

11. Describe the Whitworth quick-return motion.

12. A worm of single thread is in mesh with a worm wheel having 36 teeth. A crank of 16 inches radius is attached to the worm and a drum 10 inches in diameter is fastened to the worm wheel. How fast will the weight rise if the crank is turned 40 times per minute?

13. Suppose the press shown in Fig. 32, page 31, has a hand wheel 16 inches in diameter. The pitch $P = \frac{1}{4}$ inch and pitch $p = \frac{1}{5}$ inch. If 80,000 pounds pressure is to be exerted, what force must be applied to the hand wheel?

14. Describe some form of friction clutch.



15. In the train of gears shown, A is attached to the shaft of a motor and makes 1,000 revolutions per minute. How many revolutions per minute will gear D make?

16. If the linear velocity of the rim of a fly wheel is limited to a mile a minute, how many revolutions are allowable if the fly wheel is $7\frac{1}{2}$ feet in diameter?

17. A locomotive is running at the rate of 50 miles per hour. The drivers are 6 feet in diameter and the linear velocity of the crank pin is 24.44 feet per second. What is the length of stroke?

Note. The stroke=the diameter of crank-pin circle.

18. What is the pitch of a screw that advances 3 inches in 24 revolutions?

19. What weight can be raised by the device described in question 12 if the force applied to the crank is 110 pounds?

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